Ecological studies of a country park subjected to public pressure

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ECOLOGICAL STUDIES OF A COUNTRY PARK

SUBJECTED TO PUBLIC PRESSURE

A dissertation submitted by D. Mancey B.Sc. (Southampton)
to the University of Durham as part of the requirements
for the degree of Master of Science (Advanced Course in Ecology).

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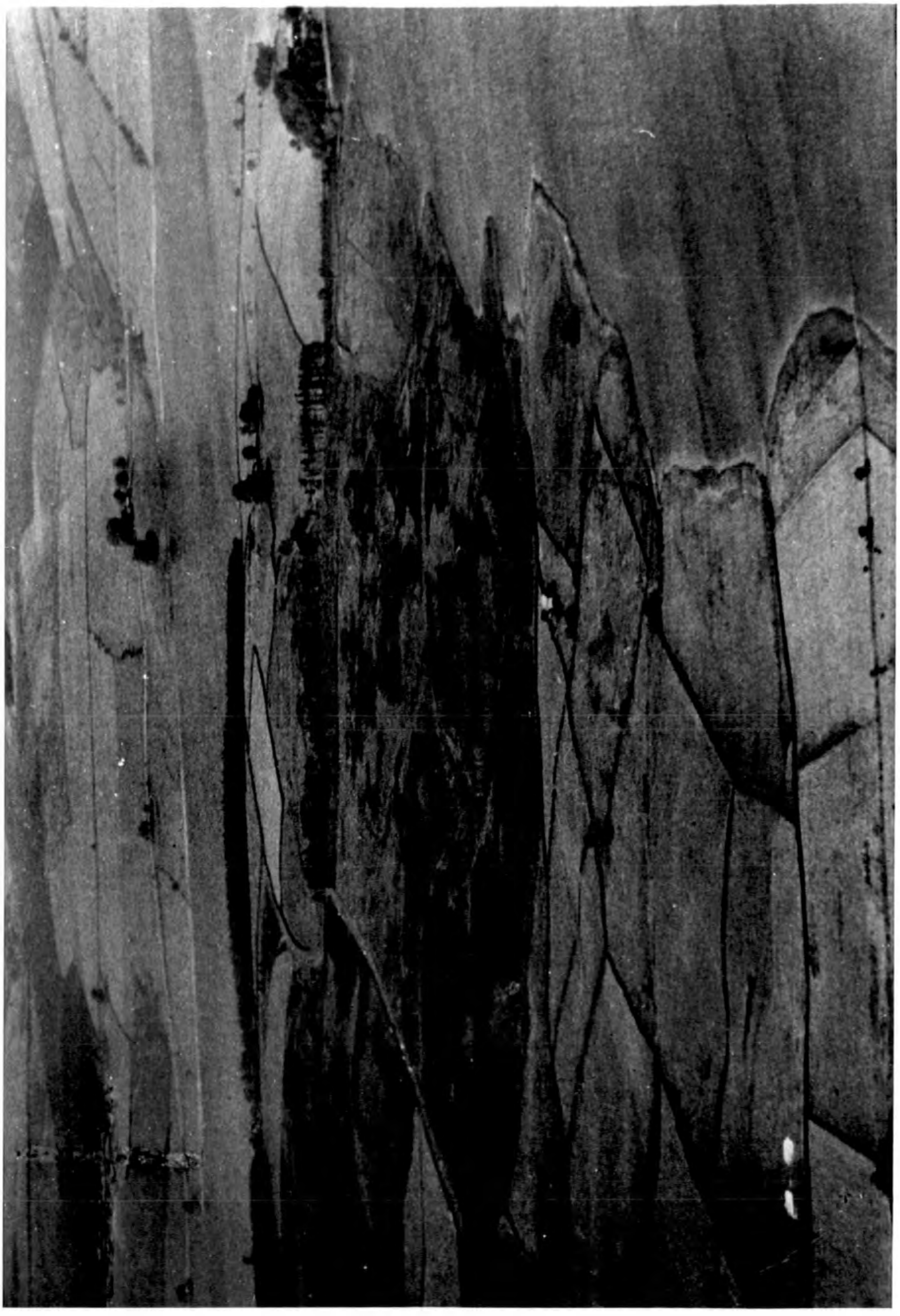


Plate 1

Pow Hill before conversion to a Country Park.

INTRODUCTION

Pow Hill Country Park lies on the southern bank of Derwent Reservoir in County Durham and adjacent to the B6306 Edmondbyers-Blanchland road, from which there is an access road into the park. There are 45 acres in the park, mainly of upland heathland, dominated by Calluna vulgaris, but through which runs a valley. The highest part of the park is 875 feet, on its southern side, dropping to 738 feet at the boundary of the park and the reservoir bank.

The natural history of the area is of considerable interest. The fine views onto Derwent reservoir make the park an obvious vantage point for ornithologists. Within the park red grouse (Lagopus s. scoticus), short-eared owl (Asio flammeus), cuckoo (Cuculus canorus), curlew (Numenius arquata) and meadow pipit (Anthus pratensis) are common. Short tailed voles (Microtus agrestis) are common in the valley region, probably benefitting from the exclusion of rabbits from the park. Adders (Vipera beris) and frogs (Rana temporaria) occur in the wetter regions of the valley, and in the numerous streams there is a wide range of aquatic fauna under the stones.

The vegetation is equally diverse. Though much of the upland areas are covered by C. vulgaris, there are considerable areas of grassland in which Pteridium aquilinum has become established. In such areas the buckler fern (Dryopteris dilatata), wood sorrel (Oxalis acetosella) and foxglove (Digitalis purpurea) are among the species found. The southern banks of the valley are intersected by wet flushes in which golden mountain saxifrage (Chrysosplenium oppositifolia), primrose (Primula vulgaris) and marsh violet (Viola palustris) are located.

The wetter regions of the valley are characterised by a well-developed valley bog community including species of bog asphodel (Narthecium ossifragum), bogbean (Menyanthes trifoliata), and crowberry (Empetrum nigrum). One location along the valley supports the grass of Parnassus (Parnassia palustris).

The land was substantially modified in 1970 by the owners, Durham County Council, with an aim of converting the area into a country park. This entailed providing leisure and recreational facilities for the public whilst maintaining the natural beauty of the landscape. To provide the public with access to the park a number of paths and open areas were made, by clearing of Calluna shrub and associated vegetation from the areas shown in figure1. These were treated with crushed Magnesian limestone to alleviate the acidity of the peaty soil. In August 1970 these areas were aqua-seeded with a seed mixture normally applied to playing fields, consisting of Chewing's fescue (Festuca rubra var. commutata), creeping red fescue (Festuca rubra) and common bent (Agrostis tenuis) in the ratio 8 : 5 : 3 respectively. The mixture was sown by the playing field staff, on their own advice, as a suitable mixture for the soil and climatic conditions at Pow Hill.

Many of the areas between the paths were ploughed and planted with a mixture of tree seedlings, the species varying according to the position. On the upland areas the planting was mainly of larch (Larix decidua) and Scot's pine (Pinus sylvestris) whilst the wetter areas had mixtures of alder (Alnus glutinosa), birch (Betula pubescens) Sitka spruce (Picea sitchensis) and lodgepole pine (Pinus contorta). A total of 24,000 seedlings were scheduled to be planted at this time, all of which were a few years old. To allow these trees maximum growth without grazing effects, a rabbit-proof fence was put around the boundary of the country park.

Provision was made at the eastern end of the valley for car parking by laying surfaced areas adjacent to the access road within the park. The ground between these areas was sown with rye grass (Lolium perenne) and a number of picnic tables and litter baskets were provided at intervals. Toilet facilities were provided in a brick built building at the point of entrance to the park. By August, 1970 a bird hide had been constructed on the park, to overlook the reservoir, with an access path from the car park area.

In September 1970, Pow Hill Country Park was officially opened, but was not used by the public until the following spring. A warden has been appointed to keep the park tidy, to control car parking at peak times and to answer visitors' questions about the park.

Further development of the area is envisaged, in particular by providing further car parking space in the remainder of the valley, on the land now covered by the valley bog vegetation. This would raise the park capacity from 150 to just under 500 cars. When this work is commenced, the drainage of the bog, extending to over three metres depth in places, will present a problem. Much of the bog community will be destroyed if this plan is implemented, reducing the vegetational variety of the Country Park considerably.

When opened in 1970, this was the first Country Park in the County of Durham. Two years later, it was clear that adverse effects had become apparent in the park, largely by the trampling action via public pressure. Most trampling was directed towards the seeded paths, though smaller paths have been badly worn, removing existing vegetation at these places. The main access path, labelled 1 on figure 1 has been given a gravel surface to assist public movement. Other paths, especially adjacent to the reservoir boundary fence, have had much of their vegetation removed by

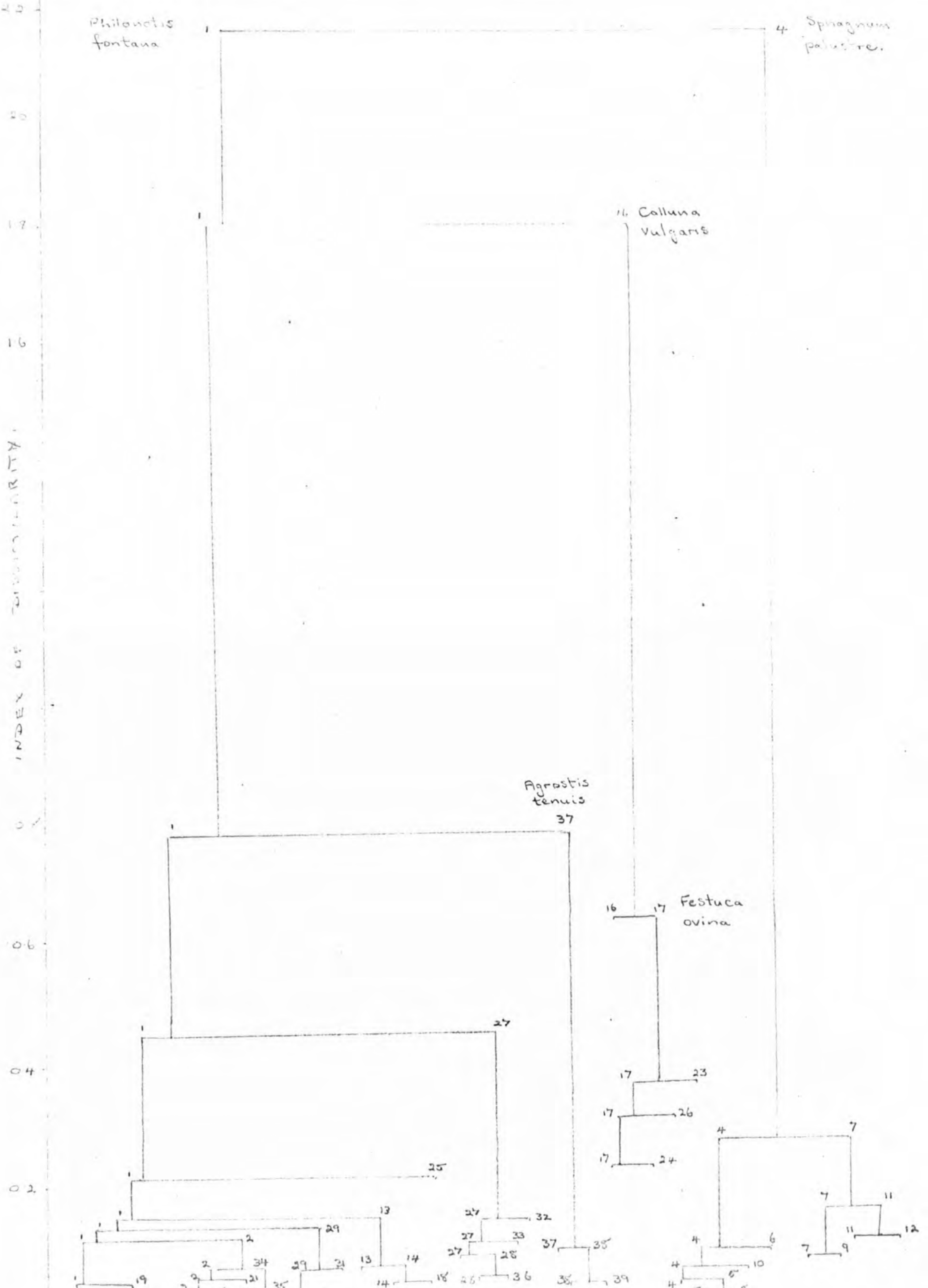
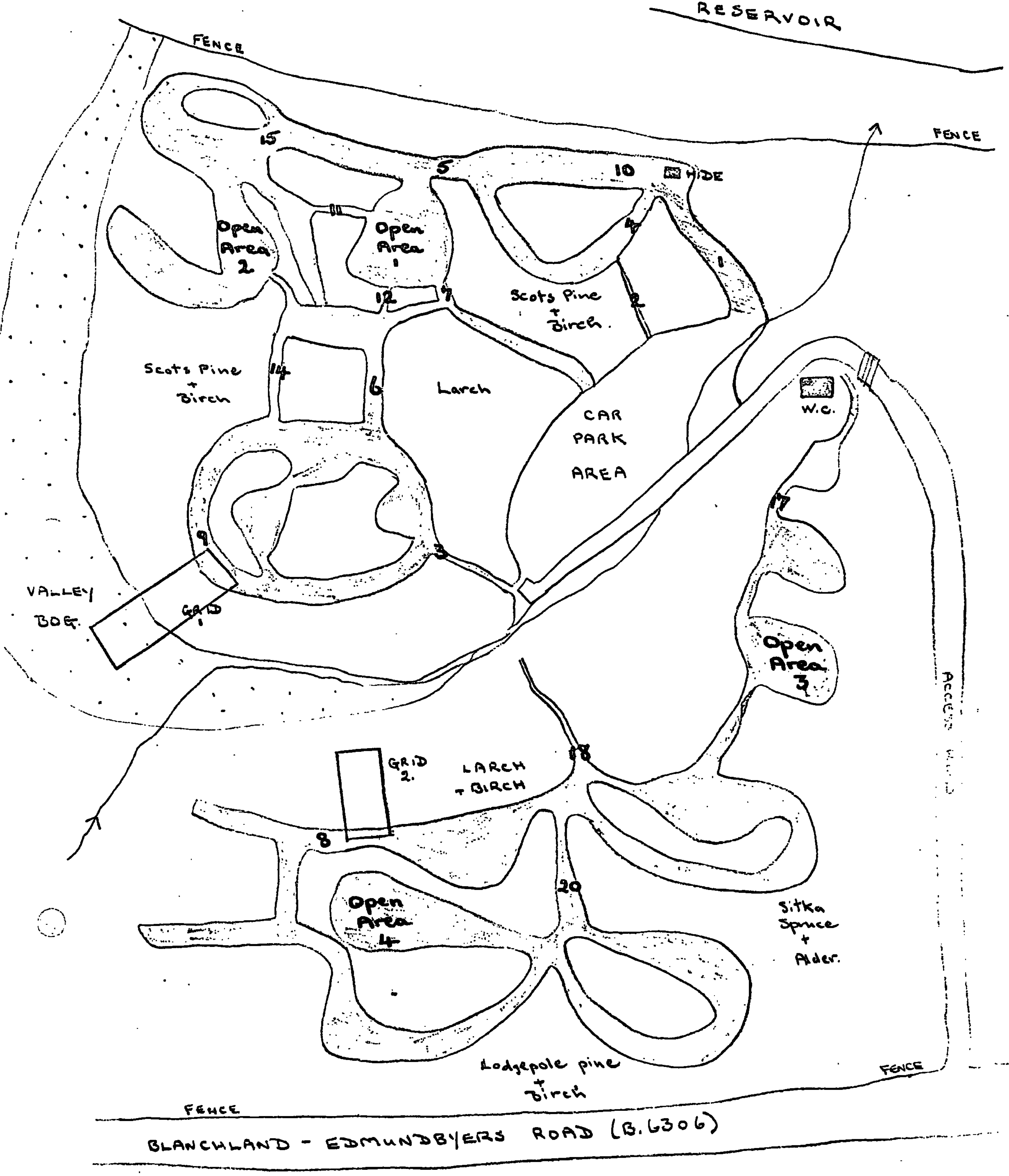


Figure 2.
Dendrogram for Grid 1.



Numbers refer to paths decribed in the dissertation.

Diagram is not drawn to scale.

Figure 1

Pow Hill Country Park. Distribution of Paths.

continued public pressure. Some tree seedlings have been either removed or damaged by the public in the vicinity of the car parking area, whilst the ground adjacent to the surfaced parking lanes has been badly damaged by car tyres.

No management plan has been produced for the Country Park to date. The work embodied in this dissertation attempts to describe the vegetation in this knowledge and to investigate the effects of public pressure on the ecology of the area with a view to providing information towards a management policy.

THE VEGETATION

Initial Survey

Pow Hill Country Park was surveyed in March, 1972 for species presence. A phytosociological approach was attempted initially, by which an understanding of the species diversity and plant communities was obtained. Though this survey proved most useful in classifying well established communities into wet heath, dry heath, grassland categories, it was not able to show the transition between these regions. The subjectivity in selecting areas for phytosociology was too great in view of the work to be undertaken later in the dissertation. In order to gain a more objective analysis, the phytosociological method was abandoned in favour of a form of association analysis.

Data collecting

Williams and Lambert (1959) using quadrats on a grid pattern, showed that such an arrangement ensured randomness of sampling, and therefore gave objectivity for the subsequent association analysis. A similar pattern of work was adopted at Pow Hill. Two grids were set out to cross all the major areas of vegetation in the Country Park and into which $1m^2$ quadrats were laid at three metre intervals. With six quadrats per row, this resulted in a 21m x 47m area on grid 1 and a 21m x 33m area on grid 2. Both grids are approximately located in figure 1. Species presence was recorded for each quadrat, the combined data being laid out in two species/quadrat matrixes. The matrixes obtained are presented in the appendix of the dissertation.

Data Handling

The field data was transferred to punched cards for analysis by a cluster analysis programme on an IBM 360 computer. One of the major aims of this programme was to separate species on a hierarchical index of dissimilarity, so identifying groupings at each level of the classification.

Results

The results are presented in dendrogram form and shown in figures 2 and 3.

Interpretation

Comparing the vegetation observed in the field with the results obtained in the dendrograms, the level of ecological validity was considered to/0.6 on both dendrograms. This gave five communities in each area which were recognisable in the field and which were objectively obtained.

Discussion

(a) Grid 1

A division between *Philonotis fontana* and *Sphagnum palustre* at the 2.16 level represented the distinction of the highly specific floras of the stream community of the valley bog, in which a more entrophic environment was maintained, and a well established bog community with its associated rise in pH and waterlogging.

The division of the *Calluna vulgaris* community at the 1.78 level was related to the dominance that this plant commanded on the drier areas of heath above the valley. It has been recognised (Watt, 1955, Barclay-Estrup, 1971) that the most dominant stage of the *Calluna* cycle is the building stage. *Calluna* at Pow Hill was mainly in the building stage, possessing all the features of that stage.

The *Agrostis tenuis* community separation at 0.76 included the areas of seeded fescues at the top of the grid. It was an unnatural grouping, in that vegetational succession would be towards one of the natural communities of the area. This factor, together with the lack of species within a grassland group should be borne in mind when the effects of public pressure are discussed. One difficulty met throughout the work was the inability to distinguish the naturally occurring *Agrostis tenuis* with that faction present in the seed mixture applied.

The absence of *Deschampsia flexuosa* from this fourth group during the analysis is rather misleading in view of its high occurrence amongst the seeded grasses. This shows *D. flexuosa* has more affinity to a natural acid grassland flora, characterised by *Festuca ovina*. This fifth division is an important one, but does not have wide distribution on the grid, owing to the presence of *C. vulgaris*.

(b) Grid 2

The first division of the grid at 2.16 separated the wet heath community, characterised by *Sphagnum palustre*, from the grassland community, characterised by *Holcus lanatus*. The wet areas, caused by a number of flushes from the hillside, support some of the bog community at the lower end of the grid, whilst on the slope subdivide into a further distinct community, as discussed below.

The presence of *Holcus lanatus* on slopes, which in grid 1 were colonised by *Calluna vulgaris*, may have been a reflection of its close relationship to *Pteridium aquilinum*, which reaches a height of over 1m. in summer. It was possible that the combined effects of shelter from wind, increased nutrient availability derived from the flushes and the consequent increased richness of vegetation, including *P. aquilinum*, may have prevented *C. vulgaris* from becoming established.

The third division at 1.22, characterised by *Hypnum cupressiforme*, included *C. vulgaris* and though distinct in the field did not dominate the area.

The fourth division at 0.86 separated the same seeded community as in Grid 1, and ~~is~~ was again characterised by *A. tenuis*. The incorporation of *D. flexuosa* into this grouping was a reflection of its inability to become established on the lower slopes, where competition from other species was greater. Scurfield (1954) has shown this species to be an opportunist of open habitats.

The division of the wet community at 0.64, characterised by Viola palustre, indicated a flush area which was sufficiently drained to prevent a bog community becoming established.

In both areas studied, communities have been identified, but in view of the difference in lengths of the grids it was not possible to combine the results. The divisions below 0.6 were not considered relevant since too often there were insufficient results to justify the separation. However, on Grid 2 it was believed that a continuum of vegetation existed in the wet regions and that despite insufficient recordings of the many species in this section of the grid, the computer had begun to illustrate this by the proportion of divisions at the lower end of the dendrogram.

Conclusions

A cluster analysis of the vegetation of two grids of vegetation has recognised seven communities of ecological significance at Pow Hill Country Park.

GRID 1

Key to species in figure 2

1. *Philonotis fontana.*
2. *Menyanthes trifoliata.*
3. *Narthecium ossifragum.*
4. *Sphagnum palustre.*
5. *Sphagnum recurvum.*
6. *Sphagnum rubellum.*
7. *Eriophorum vaginatum.*
8. *Polytrichum commune.*
9. *Erica tetralix.*
10. *Eriophorum angustifolium.*
11. *Acrocladium sarmentosus.*
12. *Vaccinium oxy-coccus.*
13. *Molinia caerulea.*
14. *Empetrum nigrum.*
15. *Salix atrocinerea.*
16. *Calluna vulgaris.*
17. *Festuca ovina.*
18. *Veronica sp.*
19. *Juncus effusus.*
20. *Chrysosplenium oppositifolium.*
21. *Holcus lanatus.*
22. *Agrostis canina.*
23. *Deschampsia flexuosa.*
24. *Hypnum cupressiforme.*
25. *Carex nigra.*
26. *Pteridium aquilinum.*
27. *Luzula campestris.*

28. Potentilla erecta.

29. Juncus squarrosus.

30. Festuca rubra.

31. Nardus stricta.

32. Dicranum scoparia.

33. Lophocolea bidentata.

34. Sorbus aucuparia.

35. Vaccinium myrtilus.

36. Galium saxatile.

37. Agrostis tenuis.

38. Mnium hornum.

39. Seeded fescues.

GRID 2

Key to Species in figure 3

1. Sphagnum palustre.
2. Sphagnum recurvum.
3. Viola palustrus.
4. Holcus lanatus.
5. Pteridium aquilinum.
6. Dryspteris dilatata.
7. Oxalis acetosella.
8. Galium palustre.
9. Chrysosplenium oppositifolium.
10. Cardamine pratensis.
11. Cirsium palustre.
12. Philonotis fontana.
13. Rananculus ficaria.
14. Juncus squarrosus.
15. Festuca sp.
16. Cerastium sp.
17. Philonotis fontana.
18. Lophocolea bidentata.
19. Potentilla sterilis.
20. Hypnum cupressiforme.
21. Brachythecium rutabulum.
22. Agrostis tenuis.
23. Rhytidiadelphus loreus.
24. Dactylis glomerata.
25. Cirsium palustre.
26. Blechuum spicant.
27. Juncus effusus.
28. Plagiothecium undulatum.

29. Festuca ovina.

30. Galium saxatile.

31. Polytrichum commune.

32. Dicranum scoparia.

33. Luzula campestris.

34. Digitalis purpurea.

35. Mnium hornum.

36. Calluna vulgaris.

37. Sorbus aucuparia.

38. Carex sp.

39. Leucobryum glaucum.

40. Vaccinium myrtilus.

41. Deschampsia flexuosa.

42. Cladonia coccifera.

43. Larix europea.

44. Epilobium angustifolium.

45. Seeded fescues.

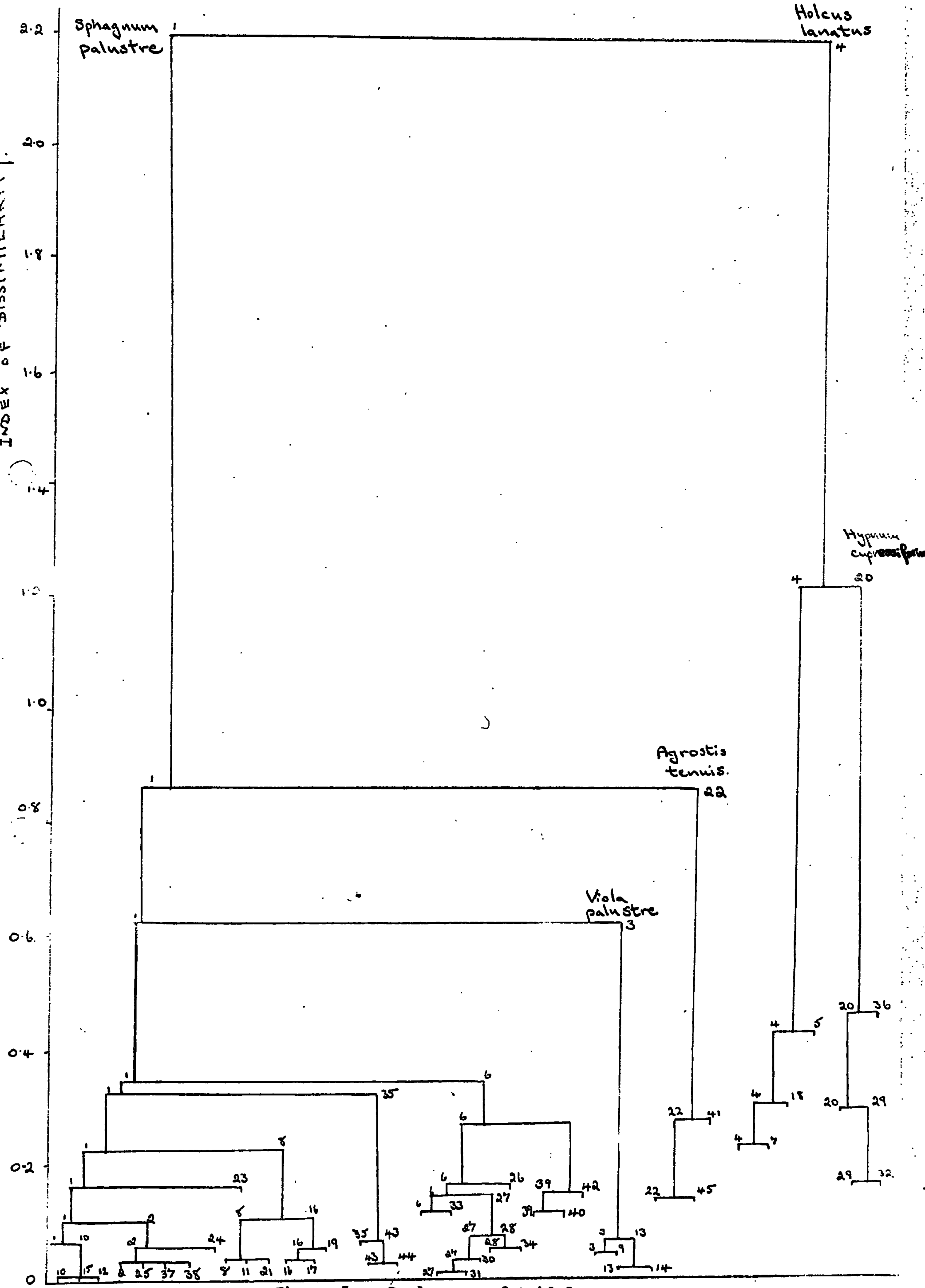


Figure 3. Dendrogram of Grid 2.

ECOLOGICAL WORK IN RELATION TO PUBLIC PRESSURE

Areas subjected to Public Pressure

During 1971, the first full year of public pressure, it has been estimated, by a combination of warden's reports (see appendix) and personal observation, that the number of cars visiting Pow Hill Country Park was in excess of 10,000 with a probable visitor total in excess of 25,000. The majority of these visitors would have taken one of the paths to the central hill to obtain a view of the reservoir, and then, either directly or indirectly, returned to their cars.

The effect of such visitor movement has resulted in certain paths adjacent to the reservoir being considerably trampled, whilst those away from this area have received far less trampling. Certain regions, such as adjacent to the picnic tables, both in the valley and on the central hill, have received further public pressure. Where managed (seeded) paths have not been formed, and for convenience of movement one was needed, visitors have created one by their own trampling. This has occurred especially on the central hill between open areas, and around the base of the hill on the bog side.

The location of paths, both managed and unmanaged, considered in the dissertation are numbered in figure 1, together with the open areas referred to in the previous comments. Both paths and open areas vary considerably in their widths, and this has been borne in mind during the studies at Pow Hill.

At the present time, the major effects of public pressure have been observed only on the areas described. The shrubby nature of <u>C. vulgaris</u> has restrained the majority of visitors from departing from the established paths and in general the public have respected the areas where tree seedling establishment is occurring. Consequently, most of the studies on public pressure have been in relation to the paths.

Unmanaged paths

Methods

In order to investigate the effects of trampling on paths, it was necessary to determine the extent of the following:-

(a) Amount of visitor pressure per path.

(b) Spread of visitor pressure across paths.

(c) Soil studies of paths, with comparisons with adjacent areas.

(d) Species presence on major paths.

(e) Species performance on paths.

The following accounts describe the approaches in detail.

(a) Amount of visitor pressure per path

Many methods are reported (Duffy, 1967) by which estimations of visitors over an area may be determined, amongst which are the use of trampleometers, time lapse photography and pin recorders. Unable to obtain sufficient equipment for the purposes in mind, the methods employed were a combination of actual observation and the use of pin recorders.

Actual observation was carried out in two ways:

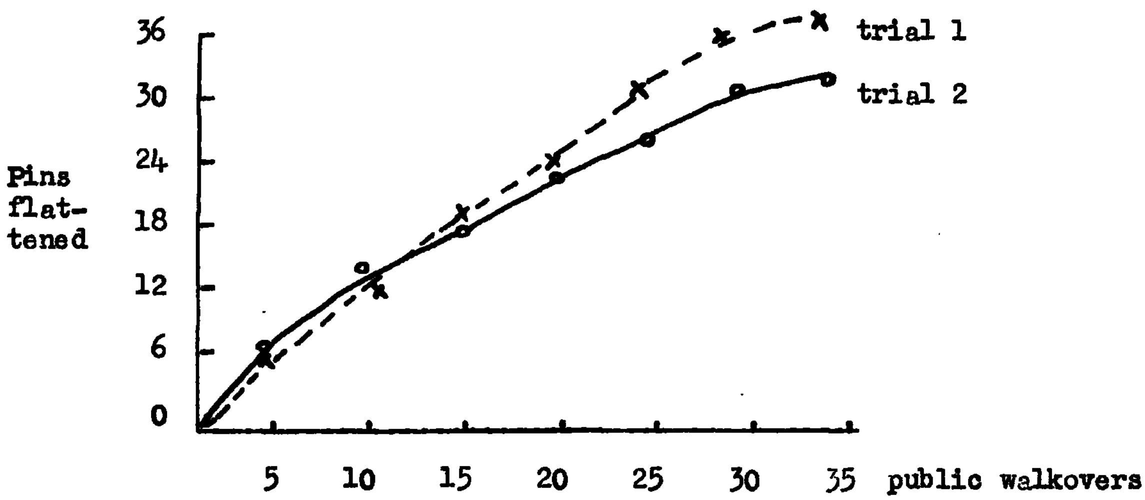
(i) Casual observation during many visits to Pow Hill for ecological work.

(ii) detailed counting of visitors over 1 hour periods at peak times on most of the paths in the study.

It was found that a location just above path 12 gave a good view of all the paths necessary, with the exception of paths 9 and 17, and it was possible to gain very reliable figures of public movement during these periods.

The use of pin recorders has been successfully used (Bayfield, 1971) on mountain paths in Scotland. A similar approach was adopted for Pow Hill Country Park. After testing various wires, the use of rose wire proved suitable for recording trampling. Lengths of 8 cms. were folded over and the ends were pushed into the soil, to expose 2 cms. of pin. This ensured that no damage could occur to small children if they fell onto the pins and yet prevented the pins from being pulled from the soil during trampling. These pins could be raised after flattening for many recordings, either until they were too rusty or too contorted.

The number of pins and the distance between them was evaluated by trials carried out by myself prior to their use at Pow Hill. From these trials, the results of which are shown below, it was decided that pin spacing should be 10 cms., cover the whole of the path laterally and have a width of 50 cms., giving six pins per row.



Calibration curve for Pin Recorders during trials

On this pattern the reliability of recording could give comparable results for any path. It was not able to compare between paths, owing to the different stages at which falling away on the calibration curve was reached, and this was related to the width of the path, and in some instances, to the degree of public pressure.

The assumption was made that the pressure of trampling on any path followed a normal distribution, with the outer pins of any path being flattened last. It was clear at the start that such recorders would quickly reach saturation point on narrow paths subjected to much trampling.

(b) Spread of Visitor Pressure across Paths

The pin recorders described above were also used to detect lateral pressure across paths. The assumption was made that should pins towards the sides of any path be flattened more than a normal distribution would predict, then provided saturation point for the path had not been reached, it was likely that lateral public pressure had occurred. This work was not so relevant to unmanaged paths for reasons already discussed.

(c) Soil studies of paths, with comparisons with adjacent areas.

Soil studies were planned to determine for both path and adjacent areas:

(1) soil pH

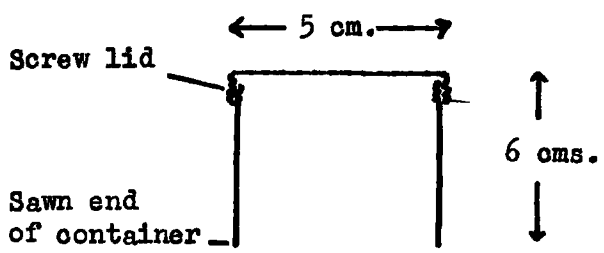
(2) soil wet weight, dry weight

(3) soil ash-free dry weight

(4) soil structure and profile

Soil pH was determined by bringing samples of surface soil to the laboratory and testing on a pH meter. Three samples per area were tested, and a mean reading obtained.

Soil weights were obtained by taking 5 cm. diameter cores of the soil to a depth of 5 cms., using an aluminium container as shown below:



With this apparatus soil cores could be easily removed without disruption by removing the lid and gently loosening. The first 3 cms. was considered more important and after cutting to this length, the samples were weighed, placed in an oven at 80°C for 48 hours and reweighed on cooling.

Ash-free dry weight was obtained from the samples described by taking known cores of 1 cm. diameter, weighing before introduction to a muffle oven at 440°C for 48 hours, and reweighing to constant weight on cooling. Three replicates were made. It was believed that the results obtained would give some indication of soil compaction.

Soil structure and profile was recorded on soil cores from both path and path side areas. This would show whether soil profiles were uniform prior to public pressure, and to give some measure of soil erosion on the various paths around the park.

It was noted during the preliminary stages of this work that Calluna stem and root remains might prove a difficulty during soil analysis. The discussion of this work deals with this aspect, in relation to the methods described for soil analysis.

(d) Species Presence on Paths

The presence of plant species across paths was recorded using a point transect method, in which species were recorded every 10 cms. across a path on three transects spaced 3 m. apart.

The use of this technique ensured a quantitative measure of a representative section of path for the percentage presence of species. It was hoped that with the results obtained, a comparison of path floras in relation to path width and trampling pressure would be possible. More elaborate methods for estimation of cover are known (Grieg-Smith, 1964) but in view of the time available and the diversity of paths to be examined, the simplest objective technique was considered sufficient for the purpose.

(e) Species Performance on Paths

In addition to species presence the height of each plant together with some measure of tillering in grasses was recorded at each point. In view of the observed density of vegetation on most paths, this approach was considered justifiable despite departing from normal point analysis.

Results

(a) Species Presence on paths

The results of path transects on unmanaged paths are given in figures 4 and 5. The percentage occurrance of species on all paths studied is shown in figure 6.

(b) Soil studies

Results of soil profiles and soil pH are incorporated into figure 17, whilst soil erosion results are given in figure 16. Ash-free dry weights

Transects of Unmanaged Paths

(figures 4 and 5)

Key

Species:

C	*Agrostis tenuis*
D	*Deschampsia flexuosa*
O	*Festuca ovina*
E	Bare soil
Total (T)	Total species per 5 points, including those not illustrated in Key.

Notes

1. Vertical axis for each species records presence per five points.

2. Horizontal axis records distance across path in cms.

Figure 4.

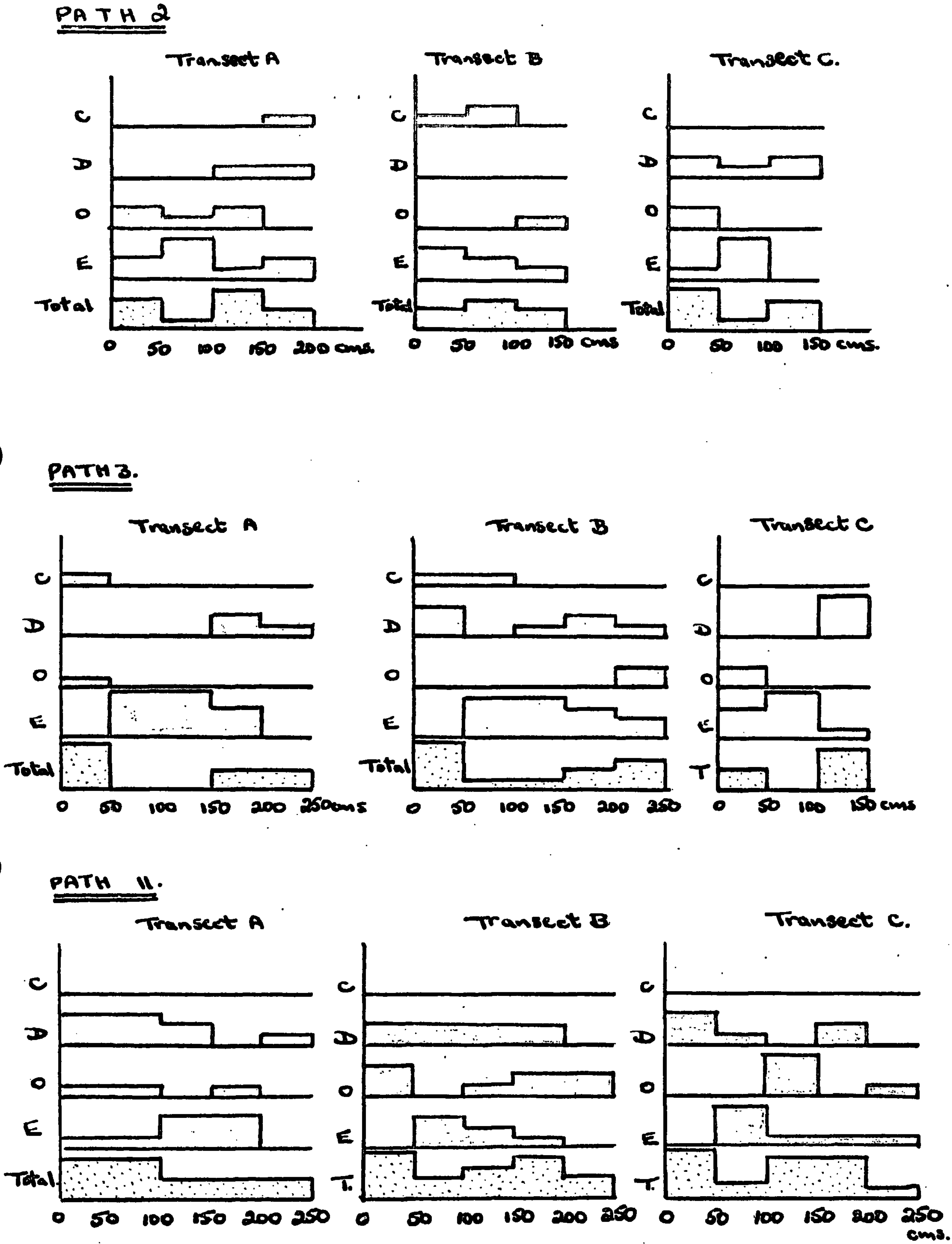


Figure 4. Species Presence.

Figure 5.

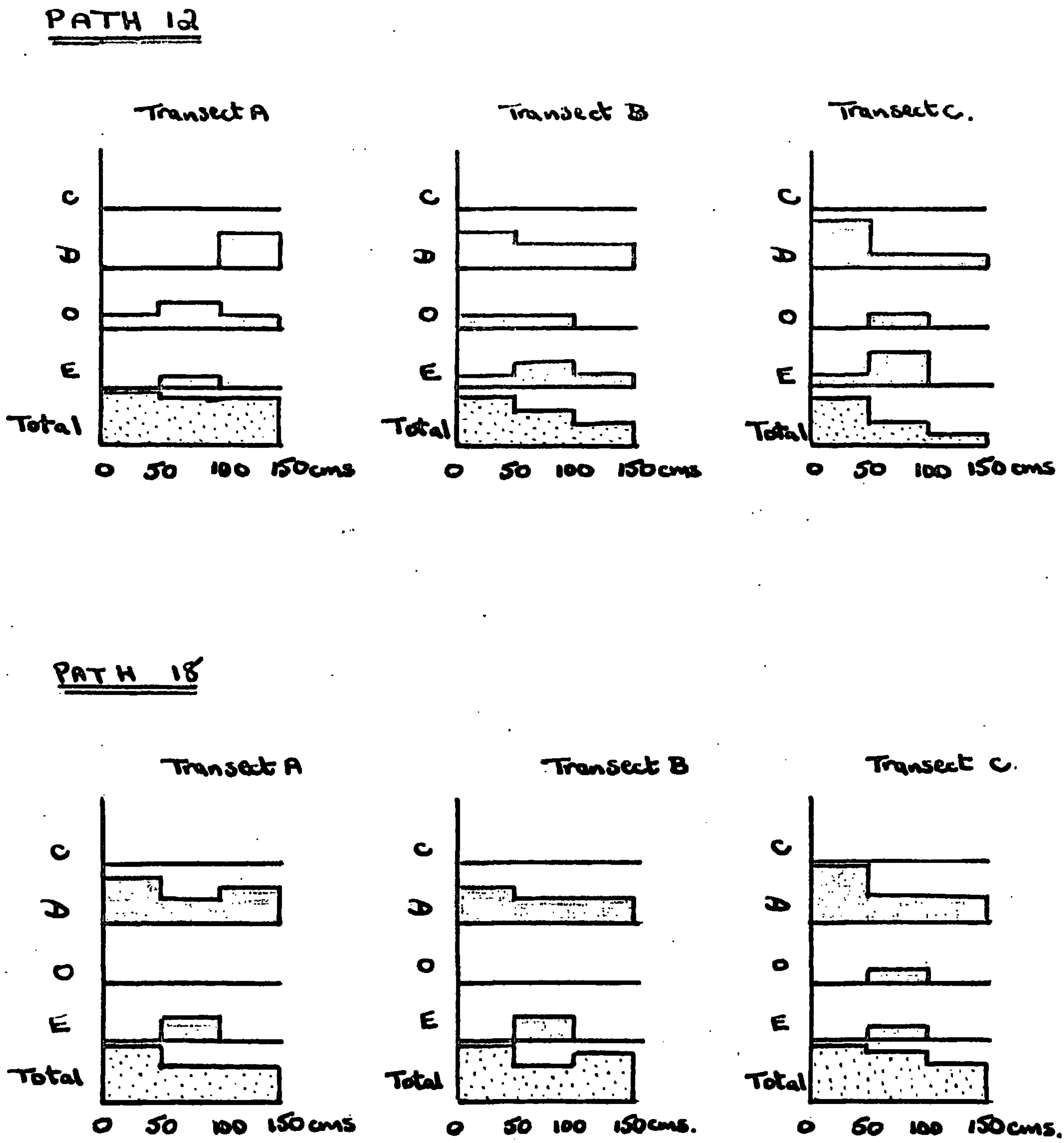


Figure 5. Species Presence.

Figure 6.

Species	Paths Percentage Occurance.				
	2	3	11	12	18
Deschampsia flexuosa	25	50	51	59	66
Festuca ovina	33	14	35	26	3
Agrostis tenuis	17	11			
Pteridium aquilinum.	4				8
Agrostis stolonifera		3			
Calluna vulgaris			2		
Poa pratensis		3		4	
Potentilla erecta	8		2	4	
Galium saxatile	8	11	2	4	5
Anthoxanthum odoratum		3		4	
Cerastium holosteoides		3			
Mnium hornum.	4				
Luzula campestris			2		3
Vaccinium myrtilus			2		3
* Bare Ground	45	55	33	25	3

* Bare ground percentages obtained from total points recorded.

Figure 6. Unmanaged Paths, Species Analysis.

are shown in figure 18, together with results from managed paths.

(c) Visitor pressure along and across paths

Visitor flow, as observed on a number of Sunday afternoons, is shown in figure 21.

Record of lateral spread, using pin recorders, is incorporated into figure 19. Since most unmanaged paths were very narrow, the need for such recording was often unnecessary.

Discussion

Vegetation analyses revealed that whereas path sides retained plant cover which showed good performance, path centres were frequently denuded of vegetation. The extent of bare soil was generally related to the amount of public pressure, and to a lesser extent, to the path width and angle of slope.

The most common species found on path sides were D. flexuosa and F. ovina. Certain paths showed P. erecta and G. saxatile associated with these species. Reference to figure 2 confirms the strong association between D. flexuosa and F. ovina in untrampled vegetation. Both were seen flowering throughout the park, including path sides, by mid-July.

Path centres tended to show differences from the path side vegetation described. Paths 11 and 12, less frequently trampled, retained a vegetation corresponding to path sides. Paths 2 and 3 were too trampled to maintain cover, and F. ovina appeared more susceptible to trampling pressure. In sections severely trampled, especially on path 3, occasional plants of A. tenuis and Poa pratensis were surviving. Both plants have morphologies suitable to withstanding public pressure (Bates, 1935; Lapage, 1967). It is likely that in the absence of plant competition, their survival was attributed to morphological features.

It was most obvious that both C. vulgaris and P. aquilinum were unable to withstand any but the slightest public pressure despite being dominant species of the park (figures 2 and 3). The implications of this will be discussed in section 3d.

Soil studies were able to show that path erosion followed a pattern correlated to the amount of trampling. The following sequence was established:

Path 3 > 2 > 11 > 12 > 18

Erosion was greatest on paths with steeper slopes, but was related to the nature of the original vegetation. Comparative studies of breakdown of C. vulgaris swards and bracken/grassy swards was not attempted in the time available.

Soil erosion on unmanaged paths was considered an underestimated problem. From a distance such effects were not visible, owing to the capacity of C. vulgaris to grow in excess of 50 cms. either side of the paths, thereby camouflaging their presence.

Soil compaction was estimated from dry weight analyses. It increased with increased pressure, but owing to the variable surface soil type resulting from erosion, no quantitative relationship was established. Path 3 was particularly vulnerable to public pressure, since the soil type found here was not easily compacted, but was unstable and liable to further erosion.

Soil pH varied between paths but was not ~~thus~~ considered significant. Species colonising acid moorlands are known to be tolerant of ranges between 4.5 - 5.5 (Bradshaw, 1960; Rogers and King, 1972) and all the samples tested were in this range.

Visitor pressure on these paths differed from that observed on unmanaged paths (see section 3c) in that no more than one abreast was possible on most. Path 3 was seen to have two or three abreast in the middle section. This concentration of public pressure has given the erosion and vegetation effects described. Path 11, with comparatively light pressure, had considerable vegetation damage, and similar patterns were observed on other minor paths not included for detailed analysis.

Problems and future research

In the time available it was not possible to investigate the breakdown of C. vulgaris heathland by trampling. In view of the expected visitor increases planned, such work would seem most important. In this respect, some monitoring of damage would appear to be valuable.

Soil studies were restrictive, particularly since no mineral analyses were attempted. Such work could reveal nutrient status of the soil, and could be related to seed trials (see section 4). It was not possible to discover whether compaction resulted in greater nutrient availability, for although ash-free dry weights showed an increase of organic material with compaction, the C/N ratio of Calluna litter is known to be high (Gimingham, 1960). Lloyd (1971) has shown that both D. flexuosa and F. ovina are often deficient in phosphorus on acid moorlands. Such work could be applied to vegetation at Pow Hill.

It was not possible to undertake detailed autecological study of the common species on the paths. During the work, it was clear that the morphology of D. flexuosa on path centres differed greatly from that at edges. Hughes (1965) maintains that genotypic variation was often more widespread than appreciated, and it was thought that the selection of specific strains, which were able to tolerate trampling, was worthy of consideration.

(c) Managed Paths

Methods

The methods used in analysis of soil and vegetation on managed paths at Pow Hill were essentially the same as those described for unmanaged paths.

It should be noted, however, that the vegetation analysis differed in two respects from that on the unmanaged paths. Virtually all the managed paths were of much greater width, the width varying depending on the section of path considered. In such cases, special care was taken to relate the soil analysis, pin recorder analysis and vegetation analysis to the same section of path.

During the vegetation analysis of the widest paths, it was recognised that the data collected from two transects often outweighed that of the total point analysis of other paths. When this occurred, it was regarded that sufficient data had been obtained to gain an overall pattern of the flora, and further points were not taken.

Results

(a) Species presence on paths

The results of species presence across the managed paths are given in figures 7-13.

(b) Species performance on paths

The overall occurrance of species on the paths studied is shown in figure 14.

The relationship between tillering and height of *D. flexuosa*, *A. tenuis* and *F. rubra var. commutata* (Chewing's fescue) on each of the paths examined is shown in figure 15.

(c) Soil studies

Results of soil erosion in relation to path width are given in figure 16. Results of soil profiles and soil pH are presented in figure 17. Dry weight and ash-free dry weights are shown in figure 18.

(d) Visitor studies

Results of the pin recorders are given in figures 19 and 20. Flow diagrams of visitor movements through the park at peak hours are presented in figure 21. The relationship between pin recorder records and observed visitor pressure is given in figure 22.

Transects of Managed Paths

Species presence

(figures 7-13)

Key

A	*Chewing's fescue*
B	*Creeping fescue*
C	*Agrostis tenuis*
D	*Deschampsia flexuosa*
E	Bare space
Total	Total species occurrence including those not illustrated in Key.

Notes

1. Vertical axis for each species records presence per five points.

2. Horizontal axis records distance across path in cms.

Figure 7.

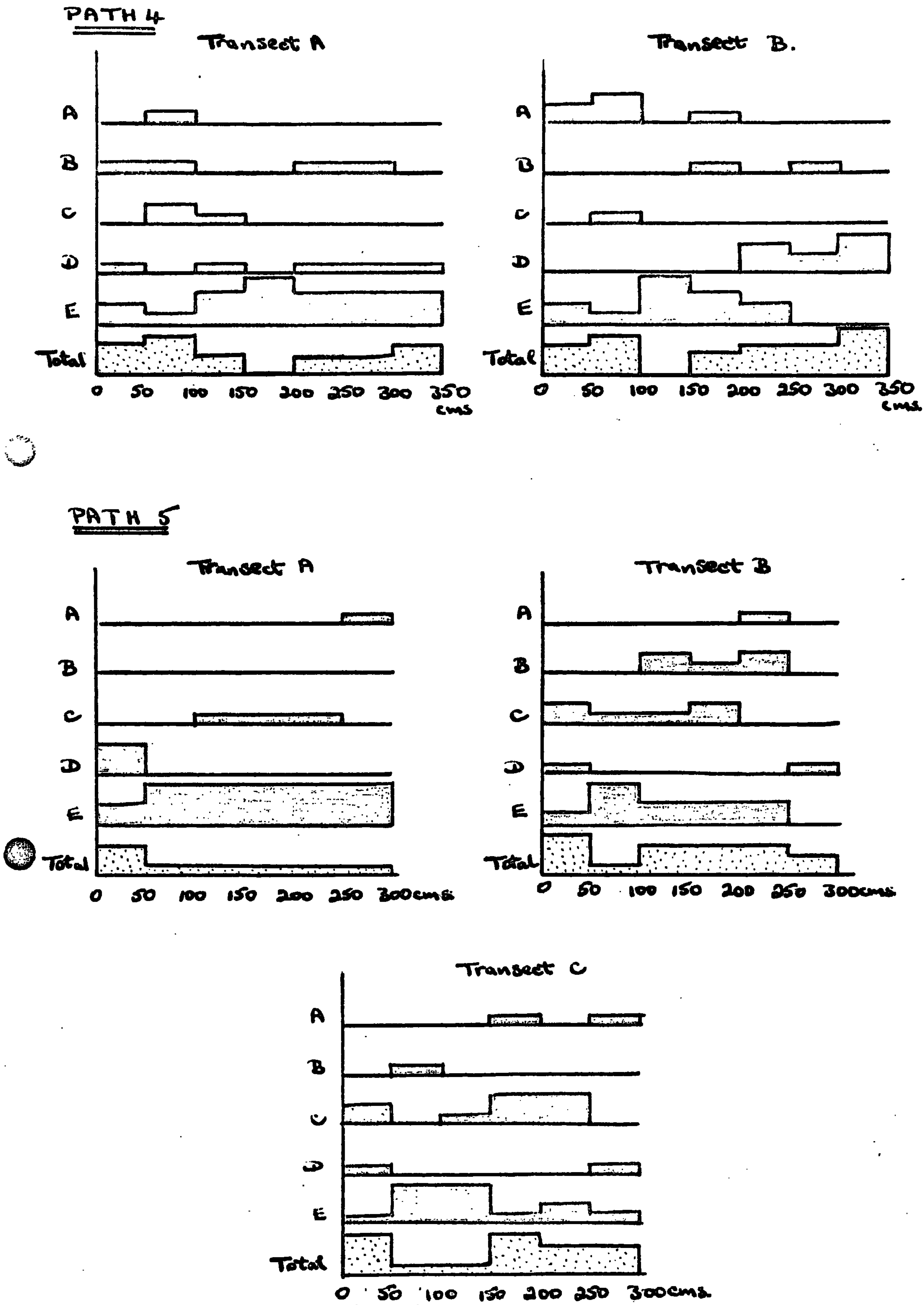
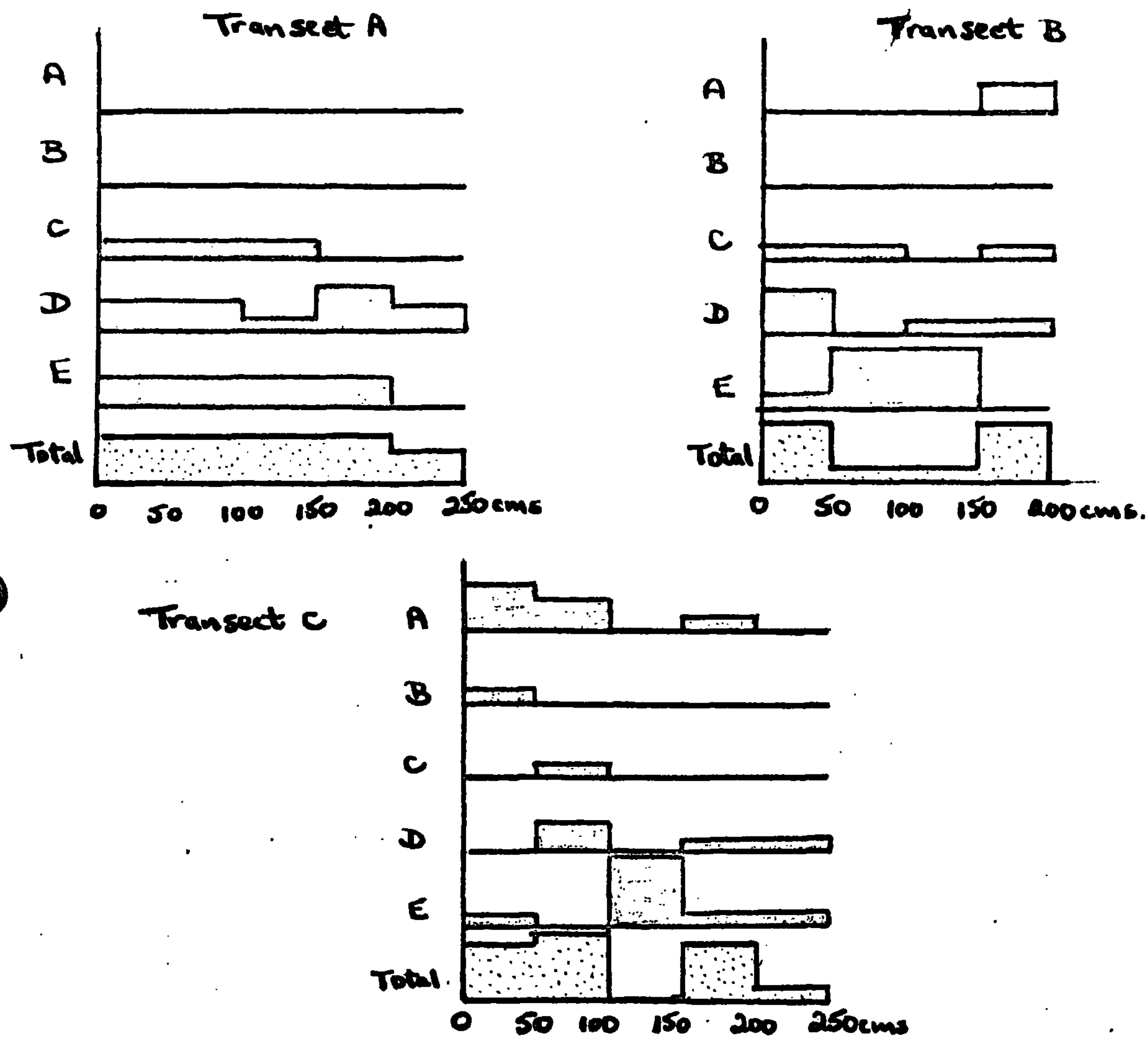


Figure 7. Species presence

Figure 8.

PATH 6



PATH 7

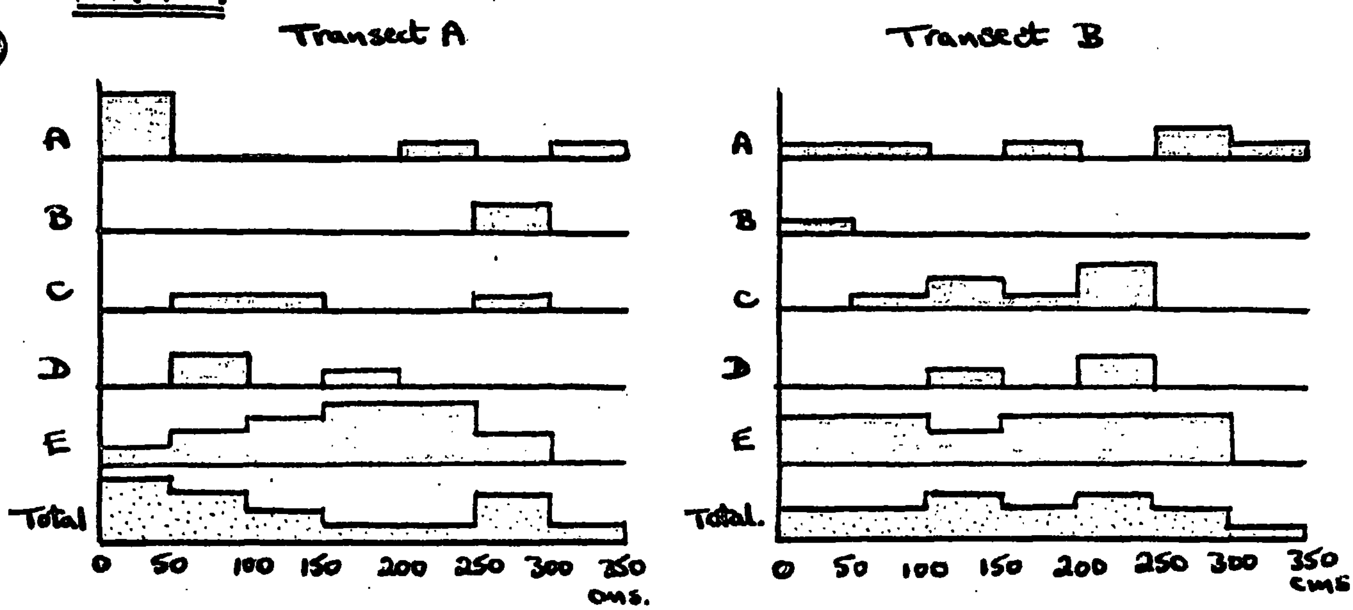
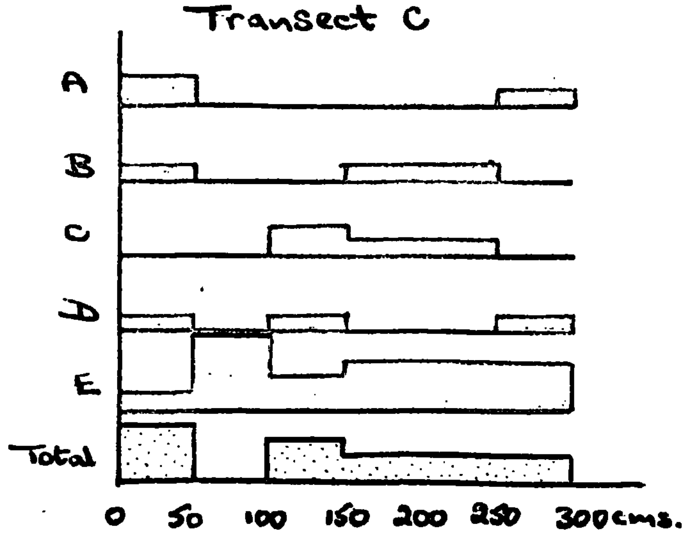


Figure 8. Species presence

Figure 9.

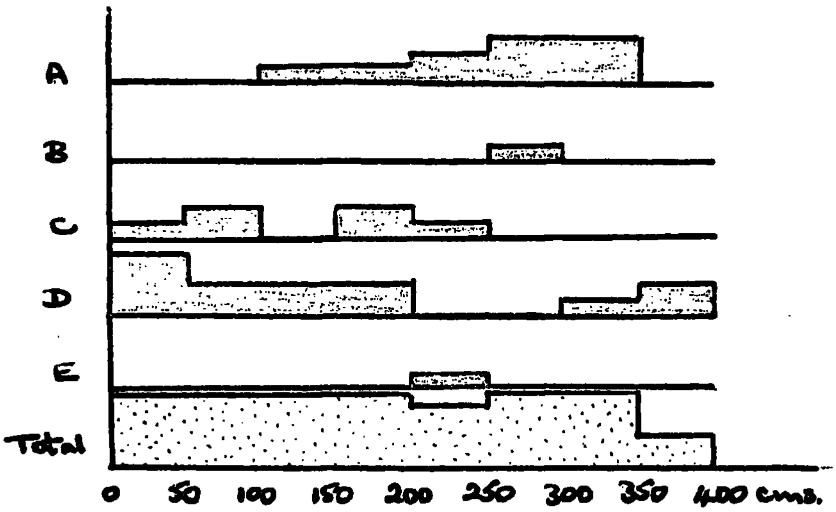
PATH 7

Transect C



PATH 8

Transect A



Transect B.

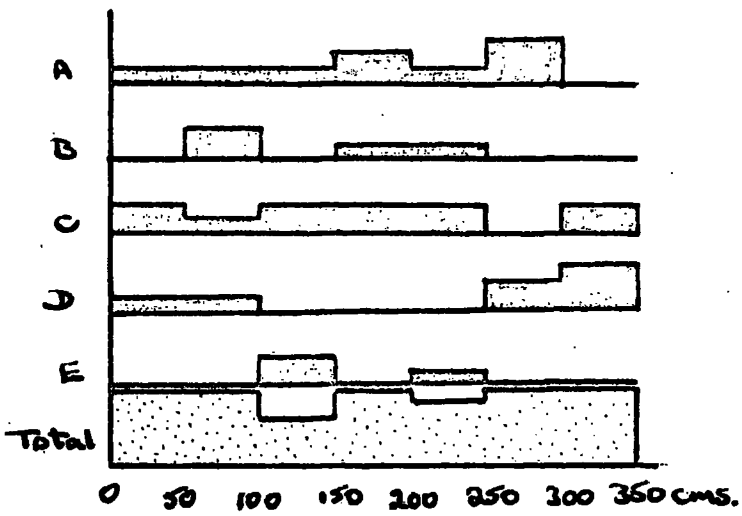
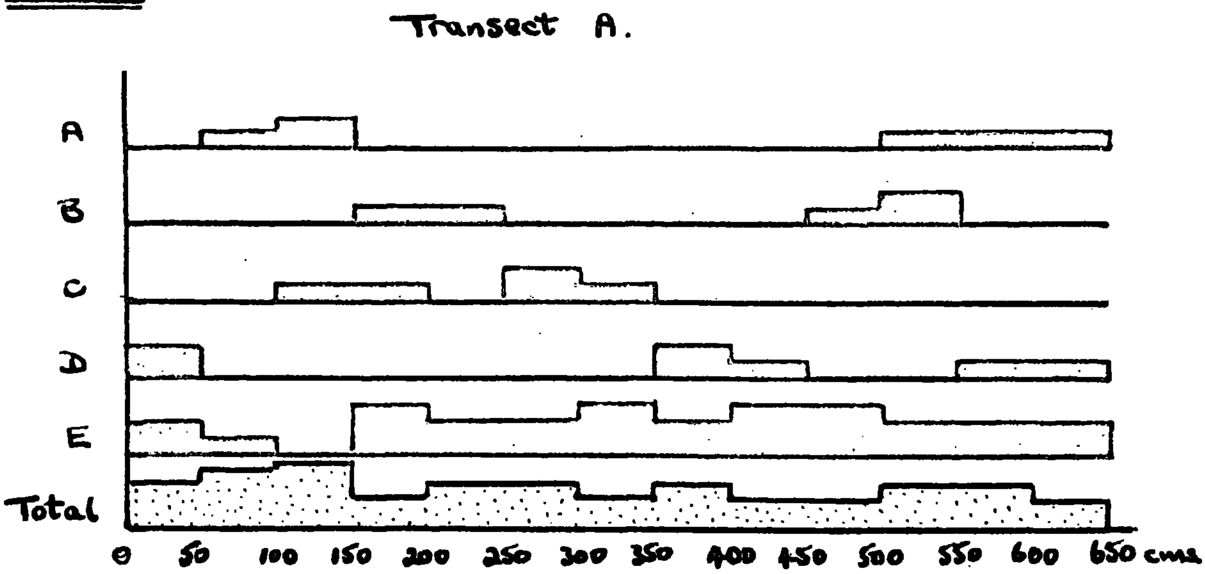


Figure 9. Species presence.

Figure 10.

PATH 9



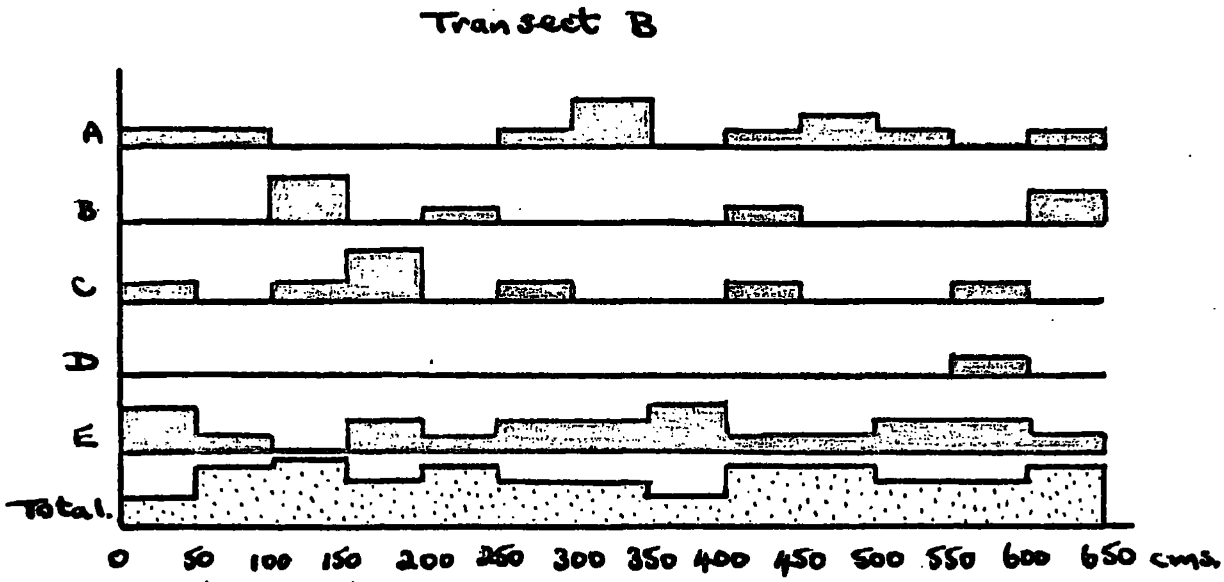


Figure 10. Species presence.

Figure 11.

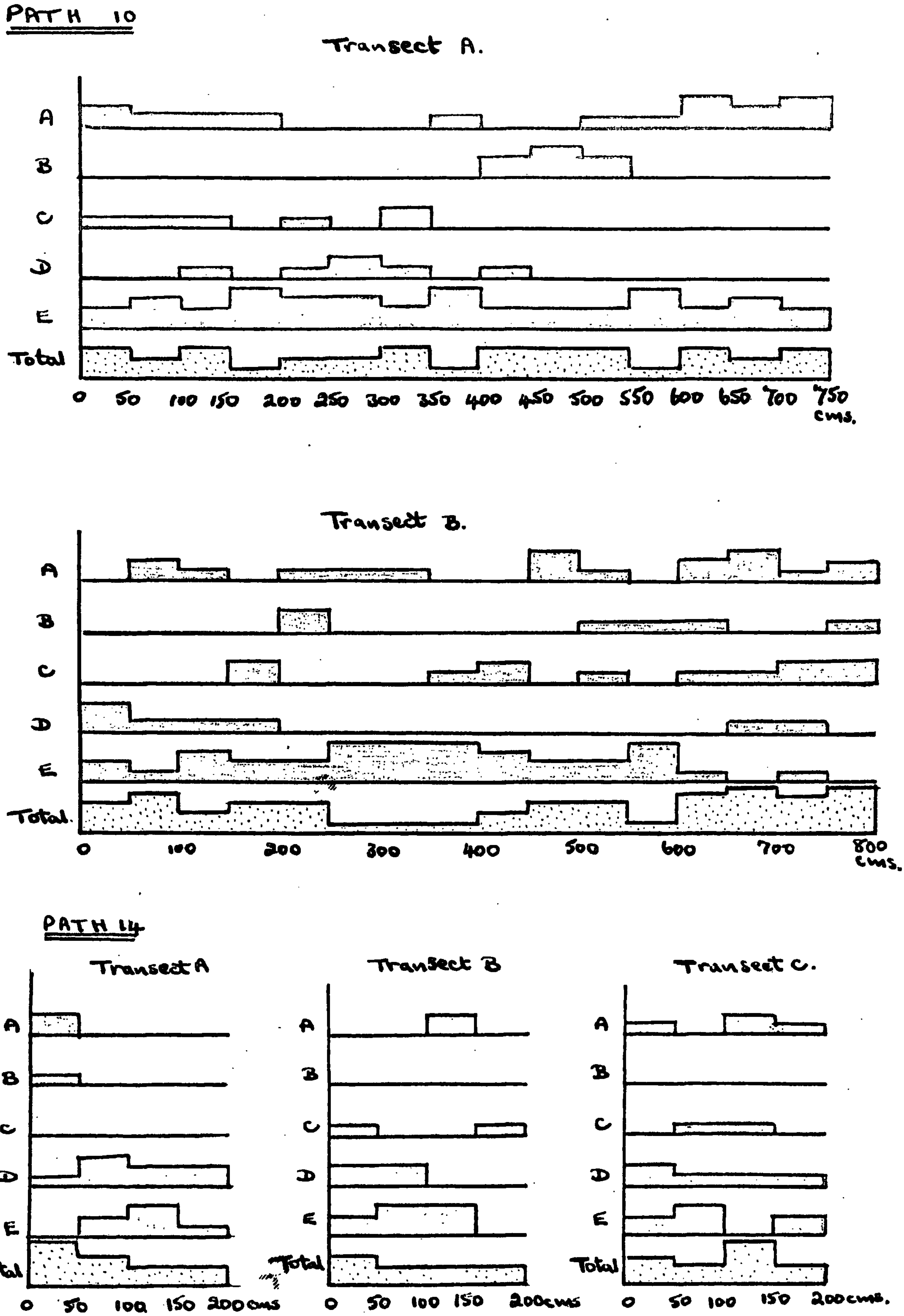
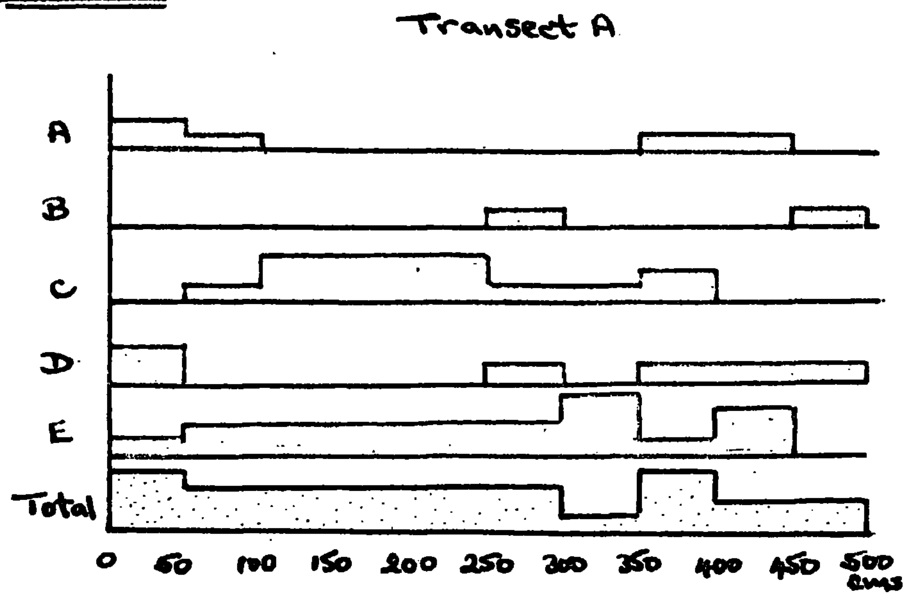
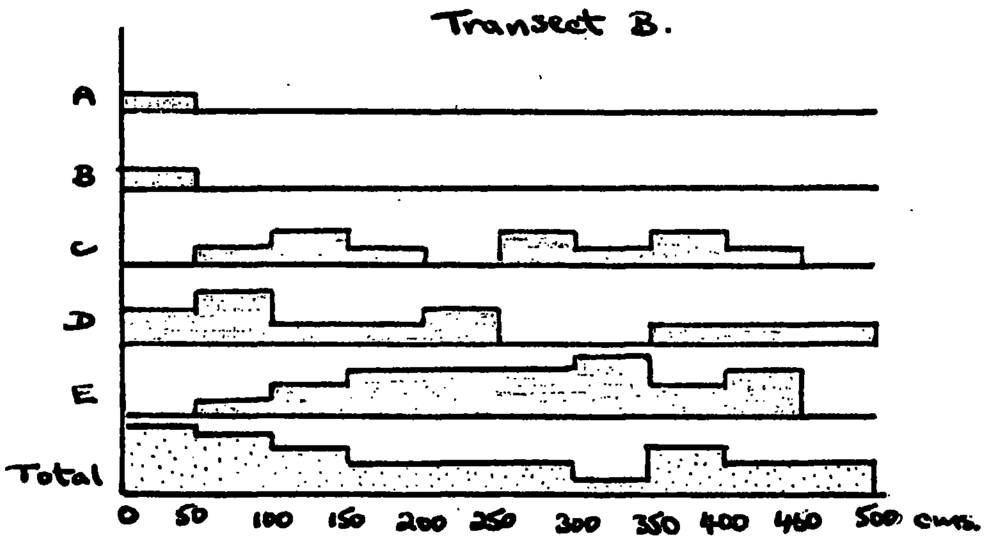


Figure 11. Species presence.

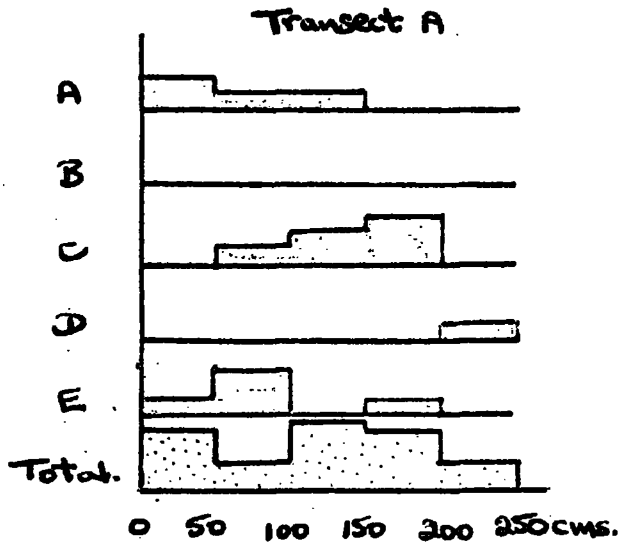
Figure 12.

PATH 15





PATH 17



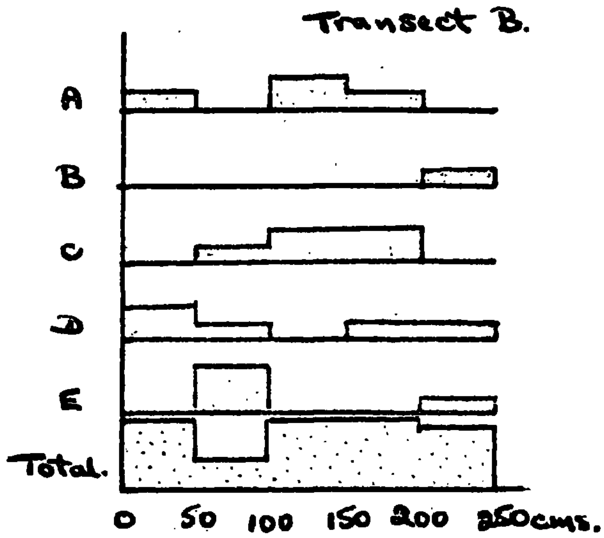
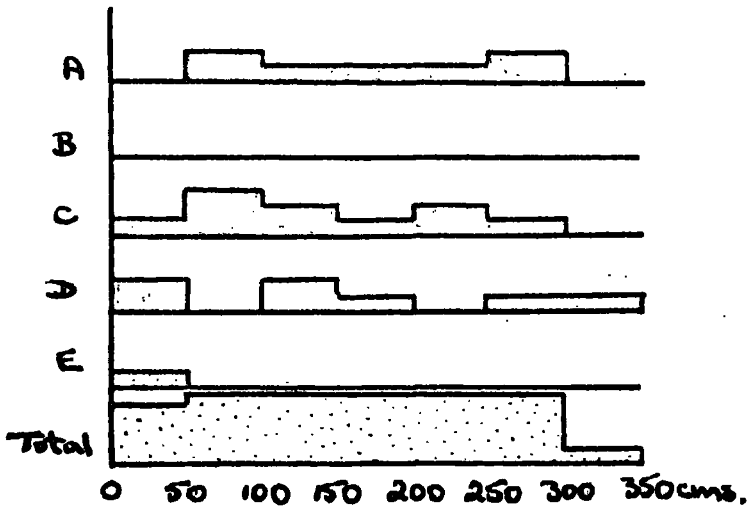


Figure 12. Species presence.

PATH 20

Transect A.



Transect B.

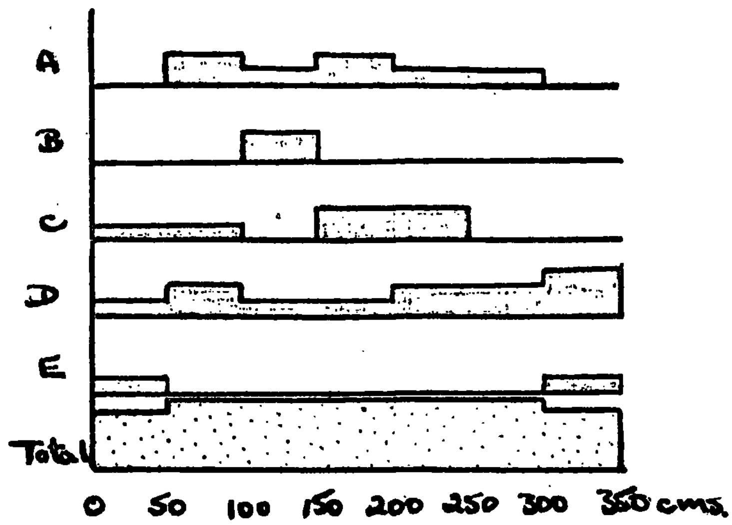


Figure 13. Species presence.

Figure 14.

Species.	Paths Percentage Occurance.										
	4	5	6	7	8	9	10	14	15	17	20
Chewing's fescue	19	8	21	34	29	21	42	22	11	20	21
Creeping fescue	14	15	3	14	7	15	16	3	6	2	3
Agrostis tenuis	11	46	18	32	26	16	23	12	45	28	23
Deschampsia flexuosa	30	18	50	16	29	10	17	53	32	15	30
Calluna vulgaris	3		3		7	32	1	3	4	5	14
Pteridium aquilinum	8			2		4					
Festuca ovina	3				1				2		
Agrostis stolonifera			3		1	1		6		15	3
Poa annua				2							
Poa pratensis		3	3								
Hypnum cupressiforme	3					1					
Cerastium holosteoides										2	
Trifolium repens										2	
Mnium hornum											
Potentilla erecta	3										
Galium saxatile											
Anthoxanthum odoratum											
Dicranum scoparium	5	8								2	
Vaccinium myrtilus		3									
Poa trivialis										5	
Bare Ground	50	55	40	53	5	38	48	37	43	20	5

Figure 14. Managed paths analysis.

Figure 15.

(a) Frequency of Tillering.

PATH	D. flexuosa. Tillers 1	2	3	4	5	5+	A. tenuis Tillers 1	2	3	4	5	5+	Chewings fescue. 1	2	3	4	5	5+
5	1	1	2	0	1	4	2	3	1	0	4	17	0	1	0	0	1	1
7	3	1	1	2	0	3	3	3	2	4	1	10	2	1	2	0	1	3
8	3	11	4	1	0	2	4	1	2	3	1	6	1	5	9	1	0	2
10	2	2	2	2	3	3	3	5	4	3	0	4	0	7	9	3	5	10
15	0	3	3	3	1	7	1	2	8	4	2	7	0	0	5	1	1	0
17	1	1	3	0	1	0	3	5	1	0	1	1	0	0	2	5	0	1
20	1	1	2	2	2	10	7	3	3	2	0	2	2	4	6	1	0	1

(b) Tillering in relation to height of vegetation.

PATH	HEIGHT	D flexuosa Tillers 1	2	3	4	5	5+	A. tenuis Tillers 1	2	3	4	5	5+	Chewing's fescue Tillers 1	2	3	4	5	5+	Totals
5	> 3cms	-	-	-	-	-	-	-	-	1	-	-	3	-	-	-	-	-	-	4
	< 3cms	-	2	1	-	-	4	1	3	1	-	2	14	-	-	-	1	-	-	29.
10	> 3cms	-	-	1	-	3	1	1	2	1	-	-	-	-	3	6	2	2	5	27
	< 3cms	2	2	1	2	-	2	2	3	3	3	-	4	-	4	3	1	3	5	40
15	> 3cms	-	2	2	2	-	3	-	-	1	1	-	-	-	-	3	1	1	-	16
	< 3cms	-	1	1	-	2	4	1	2	7	3	2	7	-	-	-	-	-	-	30
8	> 3cms	3	11	3	1	-	1	4	1	2	2	2	5	2	6	8	1	-	1	53
	< 3cms.	-	-	-	-	-	1	1	-	-	-	-	1	-	-	-	-	-	-	3

<u>Note</u>. All figures in 15b refer to plants from path centres only.

Discussion

Species composition of paths was able to be related to the degree of public pressure. Some paths, such as 8 and 20 were virtually free from pressure, whilst paths 5 and 10 were under severe pressure. Though these effects were manifest in the vegetation and soil analyses, it was clear that on these wider paths trampling was laterally distributed (see below).

In the virtual absence of trampling pressure, healthy swards of grasses had developed. However, of the seeded species, F. rubra (creeping red fescue) did not appear to have the frequency expected. Similar results were obtained in the seeding experiments (see section 4). Without further work, no explanation of this feature is offered.

Competition between D. flexuosa and F. rubra var. commutata was probably greatest on paths 8 and 20, where plant cover and density were high. In these locations both produced good growth and flowering. The flowering of D. flexuosa was seen during May in 1972, whereas Chewing's fescue did not produce flower heads until mid-June. This difference was considered to be important in the success of D. flexuosa, since by mid-June, the chance of flower head damage by both trampling and grass mowing was high. The proportion of young plants of D. flexuosa on path 8 (figure 15), as represented by tillering, was probably indicative of seeding success of this species. Grime and Hodgson (Symposium, 1968) have shown reduced frequencies of D. flexuosa between pH range 4.0-7.0. Present work at Pow Hill, where soil pH is usually above 5.0 on managed paths, does not support this view.

In the absence of pressure, and where the liming effect is not so pronounced, some reversion to the original vegetation was observed. In particular, the ability of C. vulgaris to become established from seed on paths 8, 9 and 20 (figure 14). Poel (1949) has reported that seeding reaches a peak at pH 4.0 although other workers (Gimingham 1960) have shown a wide pH range is not unfavourable to germination. Reduced cover of C. vulgaris with trampling has been described (Goldsmith, 1970). It was considered likely that C. vulgaris would increase cover rapidly in the absence of trampling, resulting in a surface unsuitable for public use. Such a situation has already occurred on parts of path 9.

Under moderate public pressure, a reduction of plant height was accompanied by increased tillering (figure 15). In particular, this was seen on paths 7 and 10. Although path 10 was subject to high visitor usage, lateral pressure was distributed over a width of 780 cms. and this resulted in path 10 showing vegetational features in common with moderate public pressure. The virtual absence of C. vulgaris confirms previous discussion on this point, whilst the reduced frequency of Chewing's fescue towards path centres was believed to be directly correlated with the increased bare cover in these areas.

Heavy public pressure resulted in the continued loss of plant cover and a greater dependence on vegetative growth of the species remaining. The success of A. tenuis in such conditions can be attributed to such morphological features. Whether A. tenuis has colonised after removal of surface vegetation, rather than survival from the original seeding is doubtful, in view of its limited colonisation of unmanaged paths (see section 36). Its success in such conditions is well established (Davies 1938, Lapage 1967, Goldsmith 1971) whilst its ability to tolerate a range of acidic and mineral regimes has also been confirmed (Bradshaw 1960, Thurston 1968 Symposium). In view of the undoubted success of this species under heavy pressure, the possibility of reseeding such paths with A. tenuis was considered a viable proposition.

From the preceding discussion a gradient of trampling pressure was established for the vegetation. This can be shown as:

Agrostis tenuis > Deschampsia flexuosa > Creeping fescue > Chewing's fescue > Calluna vulgaris

Most resistant — Least resistant

Figure 16. Soil Erosion and Path Width.

PATH	Soil Erosion	Path width (av.)	Public Pressure
2	4·0 cms	140 cms.	Moderate
3	5·0 cms	200 cms	Heavy
4	0·9 cms	360 cms	Moderate
5	1·5 cms	290 cms	Very Heavy
6	1·5 cms	210 cms	Moderate
7	1·3 cms	310 cms	Heavy
8	0·5 cms	360 cms.	Slight
9	1·0 cms	650 cms	Moderate
10	1·0 cm	780 cms.	Heavy
11	2·9 cms	220 cms.	Moderate
12	2·1 cms	120 cms.	Moderate
14	2·5 cms.	180 cms.	Moderate
15	3·0 cms.	470 cms	Heavy
17	0·5 cms.	240 cms.	Slight
18	0·5 cms.	120 cms.	Slight
20	0·3 cm	330 cms.	Slight

Figure 17. Soil pH and soil profile results.

PATH	pH.	Soil profile.
2	5·4	5cms Peaty soil
2 side	5·2	4 cms Light humus, 1cm Peaty soil
3	5·4	5cms Humus-Peat-Mineral mixture
3 side	5·3	5cms Light humus
4	5·8	0·6cm Light humus, 4·4cms Peaty Soil.
4 side	5·6	1·5cms Light humus, 3·5cms Peaty soil.
5	6·0	3cms Peaty Soil, 2cms Peat-Mineral mix.
5 side	5·8	1·5cms Heavy Humus, 3·5cms Peaty soil.
6	5·9	3·5cms Peaty soil, 1·5 cms Peat-Mineral mix.
6 side	5·6	5cms Peaty soil.
7	5·3	3cms Peaty soil, 2cms Peat-Mineral mix.
7 side	5·5	1·3cms Light humus, 3·7cms Peaty soil..
8	6·1	4 cms Peaty soil, 1cm Peat-Mineral mix
8 side	6·1	0·5cms humus, 4·5cms Peaty soil.
9	5·7	1·5cms Peaty soil, 3·5cms Peat-Mineral mix
9 side	5·7	1cm light humus, 4 cms Peaty soil.
10	5·8	5cms Peaty soil.
10 side	5·5	1cm Light humus, 4cms Peaty soil.
11	4·9	0·5cm Light humus, 4·5cms Peaty soil
11 side	5·0	3·4cms Light humus, 1·6cms Peaty soil
12	5·1	0·9cm Light humus, 4·1cms Peaty soil.
12 side	5·2	3·0cms Light humus, 2cms Peaty soil
14	5·4	1·5cms Light humus, 3·5cms Peaty soil.
14 side	5·8	4·0cms Light humus, 1cm Peaty soil.

PATH	pH	Soil profile
15	5·0	5cms Peaty soil.
15 side	5·2	3cms Light humus, 2cms Peaty soil.
17	5·9	0·5cm Light humus, 4·5cms Peat-Mineral mix
17 side	5·9	2·5cms Light humus, 2·5cms Peat-Mineral mix.
18	4·8	0·7cms Light humus, 4·3cms Peaty Soil.
18 side	4·9	1·2cms Light humus, 3·8cms Peaty soil.
20	5·8	5cms Peaty soil.
20 side	6·0	0·3cms Light humus, 4·3cms Peaty soil

Figure 18. Dry weight and Ash-free dry weights from path samples.

Results expressed as averages of 3 samples.

PATH	Initial Dry Weight (g)	Ash-free Dry Weight (g)	Loss (percentage)	Erosion effects. (see fig. 17)
2	0·83	0·11	87	Moderate
3	1·83	1·44	21	Heavy
4	1·40	0·24	83	Moderate
5	2·54	1·11	56	Very Heavy.
6	1·08	0·17	84	Moderate
7	2·17	0·46	79	Heavy
8	1·65	1·24	25	Slight
9	1·65	0·83	50	Slight
10	2·24	0·36	84	Heavy
11	1·61	0·54	66	Moderate
12	1·50	0·65	57	Moderate
14	1·87	0·53	72	Moderate
15	204	0·81	60	Heavy
17	2·37	0·83	65	Moderate
18	1·69	0·73	57	Slight
20	1·20	0·25	79	Slight.

Figure 19. Analysis of Pin Recorders on Paths.

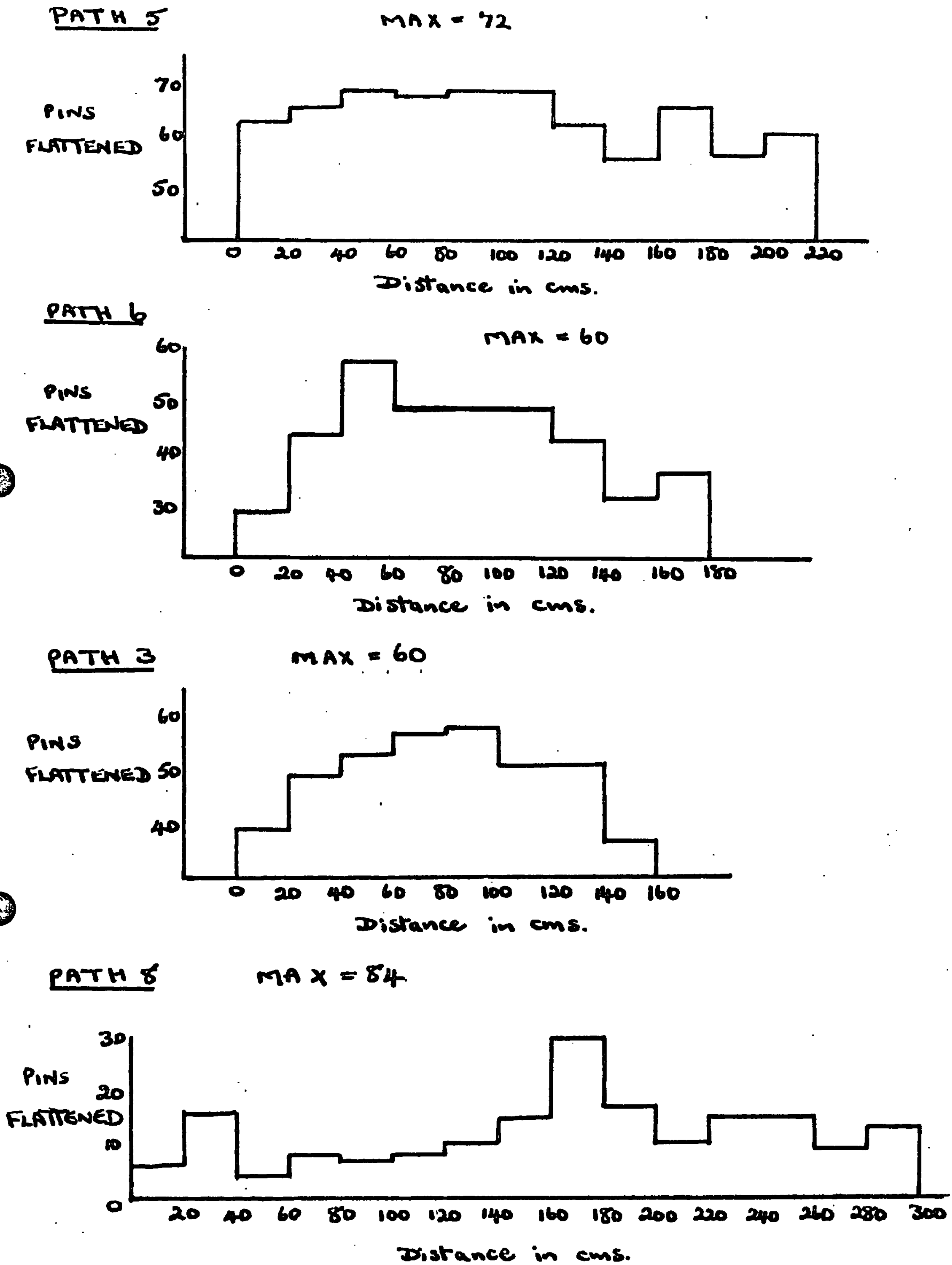
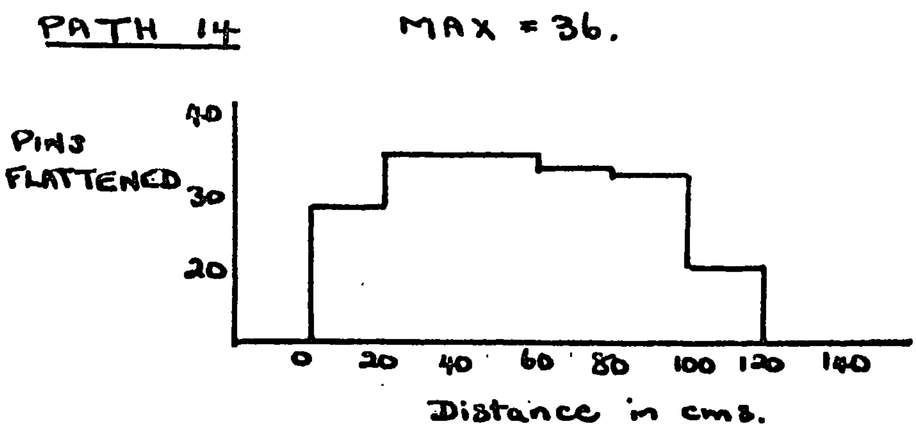


Figure 20. Analysis of Pin Recorders on Paths.



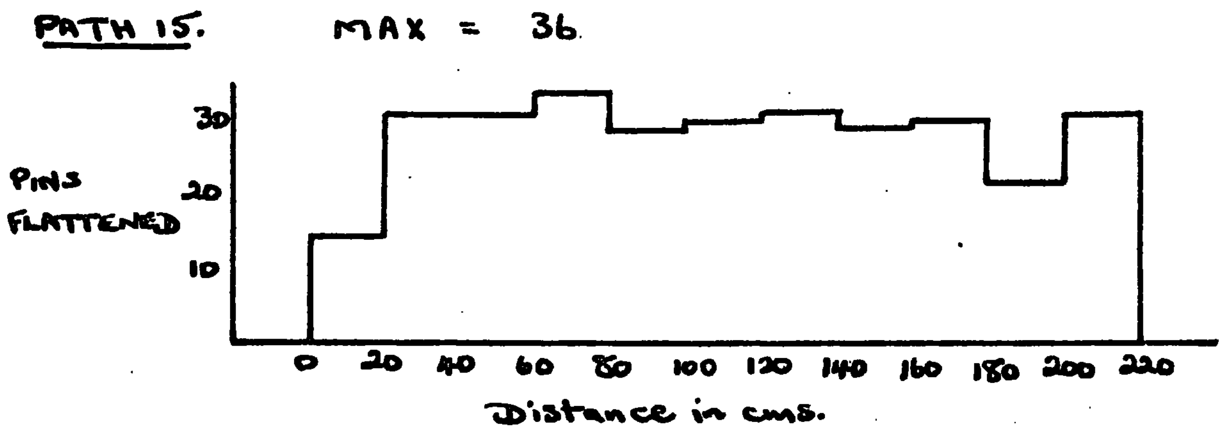
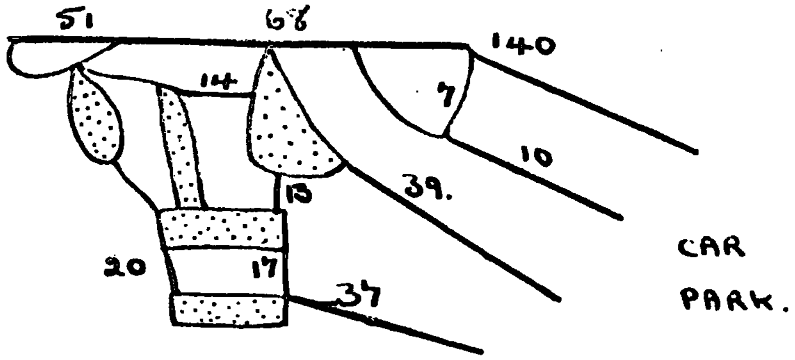
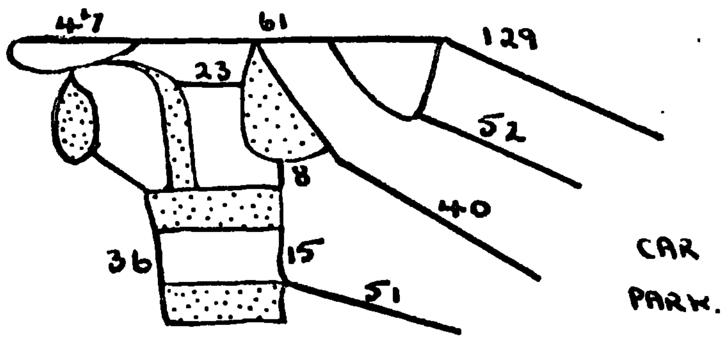


Figure 21. Flow diagrams of Visitor Movement at Pow Hill.

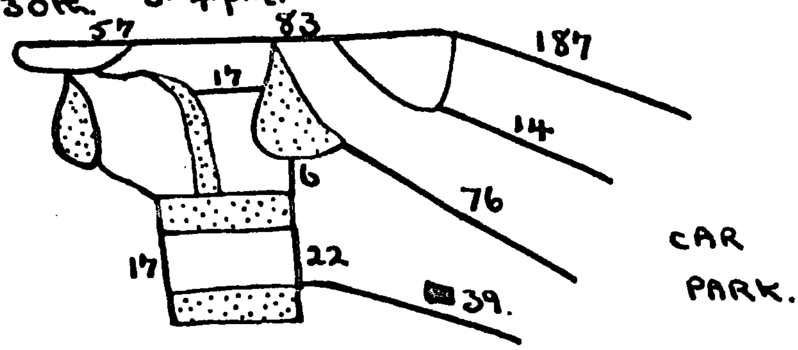
1. JUNE 18th. 3-4pm. WEATHER: COOL AND CLOUDY.



2. JUNE 18th 3-4pm. WEATHER: CLOUDY WITH SUNNY PERIODS.



3. JULY 30th. 3-4pm. WEATHER: DULL AND CLOUDY.



4. AUGUST 13th 3-4pm. WEATHER: SUNNY AND WARM.

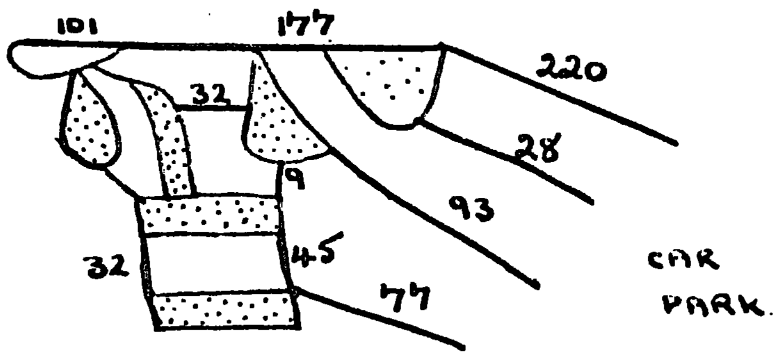


Figure 22. Relationship between Pin Recorders and Public Pressure.

PATH	Observed visitor pressure (Ratio)	Proportion of Pins flattened as a ratio of path width.
2	3·1	——
3	4·4	1·1
4	0·9	——
5	6·4	1·2
6	1·4	1·4
7	4·0	1·2
8	0	8·6
10	13·4	——
11	1·8	——
12	1·0	——
14	2·8	1·6
15	4·9.	2·5.
20	0	——

Soil studies (figure 16) revealed that erosion was directly related to path width. Maximum erosion was never so severe as on the unmanaged paths (section 36), but was sufficient to remove surface litter, and possibly reduce nutrient availability for the grasses. Both of the major paths from the car park (figure 1) were devoid of vegetation, path 1 having been treated with gravel to assist public walking to the bird hide. Their continued heavy use would probably lead to some further erosion, but unlike path 3, the soil profile has indicated that, under moderate pressure, the compacted soil can withstand some degree of pressure.

Soil dry weights have shown that compaction has occurred in response to public pressure (figure 18). Ash-free dry weights on some paths examined, indicated that more humic material was available following compaction, but C/N ratios for <u>Calluna</u> soils are high (Gimingham 1960). Further mineral application may prove worthwhile in these situations.

Soil pH was not considered to be an important factor in the ranges recorded.

Visitor pressure followed a similar flow on the occasions it was observed (figure 21). Greatest pressure was on the paths adjacent to the reservoir. The pattern of family parties in spreading across paths was both seen, and confirmed, by the pin recorders (figures 19 and 20).

Many visitors did not attempt to go beyond the bird hide whilst the southern hill was virtually neglected. The reasons for this are considered in section 5.5. On good sunny weekends, the warden (pers. comm.) has reported that this pattern breaks down under the increased density, resulting in a gradual spread over other areas of the park. This occurred on many days in 1971, but happened only once between April-August, 1972, owing to the lack of sunny days.

One aspect of pressure not apparent from the results was related to the effects of children. Both during the surveys, and on numerous occasions on weekdays, children were seen to run along paths, between lines of tree seedlings and make their own paths through untrampled

C. vulgaris swards. Such activity greatly increases the rate of soil erosion and vegetation deterioration. Providing a natural playground for children, it is a favourite visiting area for school and church parties. It would be better if such activity was directed towards the southern hill to deter the spread of C. vulgaris seedlings on those paths, rather than accelerate damage on the central hill.

Problems and future work

Further mineral analysis would have yielded information related to availability of phosphorus and nitrogen. From this knowledge, some decision of application of further fertilizer or seed could have been made.

Further studies on A. tenuis would have been valuable, to determine its ability to withstand public pressure.

Some photographs were taken of certain paths subjected to heavy pressure. It is hoped that a continuous photographic record be made each summer following this survey, to determine trends in plant colonisation and destruction.

(d) Managed Open Areas

Methods

A number of open areas were analysed for soil type and vegetation status. Though public pressure appeared to be slight on these areas, since they were an extension of a wide managed path, their study might reveal information which was not apparent from the path analysis.

The soil was analysed for pH, profile and erosion, in the manner described for the unmanaged paths. Dry weights and ash-free dry weights were not attempted.

The vegetation was analysed using $1m^2$ quadrats for presence, set out in a grid with a distance of 5m between quadrats. This was not considered satisfactory from the point of view of research method, but was practicable in the time available.

Results

The results of the plant analyses are shown in figures 23-26. Results are expressed as percentages in order that areas are comparable.

Soil analyses are given below. Results were derived from three samples per area:

Location	pH	Profile	Erosion
Open Area 1	5.8	(1 cm. light humus (4 cm. peaty soil	1.1 cm
Open Area 2	5.1	5 cm. peaty soil	Nil
Open Area 3	5.6	(0.5 cm. light humus (4.5 cm. peaty soil	Nil
Open Area 4	6.0	(0.5 cm. light humus (4.5 cm. peaty soil	Nil

Discussion

In all open areas, there was widespread occurrance of D. flexuosa, F. rubra, A. tenuis and F. rubra var. commutata, producing a good sward, suitable for public recreation. Open areas 1 and 2 were often used for this purpose, whilst areas 3 and 4 were rarely used.

The pattern of vegetation in relation to public pressure followed that described for managed paths. Areas 3 and 4 showed considerable growth of Calluna, both in seedling form and as regeneration of existing stems. A corresponding increase of Pteridium aquilinum was also noticed, confirming the trend of reversion to a Calluna community isolated in figure 2.

This reversion, at present in its early stages, has been accompanied by an open community of minor significance in figure 2, including Luzula campestris and Potentilla erecta.

The occurrence of isolated groups of Trifolium repens, a nitrogen-fixer, is of interest, since this species has successfully invaded the car park area, despite pressure from tyres, and may be extending onto the

Figures 23 - 26

Analysis of Open Areas,

Results

Open Area No 1.

Public Pressure

SPECIES	LIGHT	MODERATE	HEAVY	TOTAL	PERCENTAGE OCCURANCE
Chewing's Fescue	12	7	8	27	87
Creeping Fescue	4	3	4	11	36
Agrostis tenuis	14	7	10	31	100
Deschampsia flexuosa	14	7	10	31	100
Calluna vulgaris	10	6	2	18	58
Pteridium aquilinum.	13	6	6	25	81
Festuca ovina	9	3	5	17	55
Agrostis stolonifera	7	4	0	11	36
Vaccinium myrtillus	6	0	0	6	19
Potentilla erecta	6	0	1	7	23
Hypnum cupressiforme	4	0	0	4	13
Polygala serpyllifolia	1	0	0	1	3
Holcus lanatus	2	0	0	2	6
Galium saxatile	2	0	0	2	6
Luzula campestris.	3	0	0	3	10
Anthoxanthum odoratum	1	0	0	1	3
Leucobryum glaucum.	1	0	0	1	3
Cerastium holosteoides	1	0	2	3	10
Polytrichum aloides	1	2	2	5	16
Poa annua	0	0	1	1	3
Poa pratense.	0	1	2	3	10
Poa trivialis	0	1	0	1	3

Open Area 2.

34 quadrats:

Species.	Occurance	Percentage occurance
Chewing's fescue	29.	85.3
Agrostis tennis	31	91.2
Creeping fescue	23	67.6.
Agrostis stolonifera.	20	58.8
Deschampsia flexuosa	20	58.8.
Calluna vulgaris	18	52.9.
Nardus stricta	14	41.2.
Carex nigra.	5	14.7
Juncus squarrosus.	3	8.8
Vaccinium myrtilus	3	8.8
Festuca ovina.	2	5.9.
Holcus lanatus	1	2.9
Erica tetralix	1	2.9
Poa trioialis	1	2.9
Pteridium aquilinum	1	2.9
Hypnum cupressiforme	1	2.9.

Open Area 3.

25 Quadrats : 17 Species.

Species	Occurance	Percentage Occurance
Chewing's Fescue	25	100
Calluna vulgaris	24	96
Deschampsia flexuosa	24	96
Agrostis tenuis	23	92
Agrostis stolonifera.	12	48
Creeping Fescue	10	40
Pteridium aquilinum	5	20
Holcus lanatus	2	8
Erica tetralix	2	8
Luzula campestris	2	8
Galium saxatile	1	4
Potentilla erecta	1	4
Festuca ovina	1	4
Carex sp.	1	4
Juncus effusus	1	4
Dicranum scoparium	1	4
Mnium hornum.	1	4

Open Area 4.

33 Quadrats: 14 Species

Species	Occurance.	Percentage occurance
Calluna vulgaris	33	100
Chewing's Fescue	30	90
Deschampsia flexuosa	30	90
Agrostis tenuis.	27	81
Agrostis stolonifera	12	36
Creeping Fescue	11	33
Pteridium aquilinum	4	12
Trifolium repens	2	6
Luzula campestris	2	6
Dactylis glomerata.	2	6
Holcus lanatus	1	3
Rumex acetosella	1	3
Poa pratensis	1	3
Epilobium angustifolium.	1	3

managed areas. Bates (1935) has shown that the morphology of T. repens ~~Calluna~~ allowed its survival on footpaths, and if this was happening at Pow Hill, it would be of immense value to the associated grasses. Opportunists, including weed species, have taken advantage of the open habitat, and their spread would be worth monitoring in future.

Area 1 was exceptional for its species diversity. The range of trampling pressures towards the centre of the area, together with fringe areas of limited cover, have resulted in both reversions and introductions ~~having~~ occurred.

Under slight pressure, open habitat species, including A. stolonifera have become established. Good moss growth was recorded from this area.

Areas of heavy pressure were often devoid of vegetation. In such cases, the establishment of Poa pratensis and Cerastium holosteoides were noted. Given time, it is likely that they may be followed by other species, capable of withstanding trampling.

Area 2 differed from most other areas, being on wet ground, supporting Nardus stricta and increased amounts of Festuca rubra. Under such conditions, it was noted that D. flexuosa had a reduced cover, possibly a result of increased competition from wet-loving species.

Problems and further research

The major problem was that of vegetation analysis. The use of point quadrats would have given far greater objectivity to the results. Further quadrats, at shorter intervals, would have given data of the relative abundance of the weed flora. Such information could have been used as a start for an annual analysis of weed flora abundance.

EXPERIMENTAL WORK ON SEED MIXTURE

Introduction

To obtain information on the suitability of the grass mixture seeded at Pow Hill and relationship to the management of the area, work was carried out on this mixture during the summer of 1972. The performance of the grasses under a range of soil conditions was examined, as was the viability and germination of the seed mixture.

Methods

Germination of the seed mixture took place in petri dishes lined with damp filter paper. Counts were made after seven days on each of the species.

Seeding experiments were carried out in 7.5 cm^2 pots filled with peaty soil obtained from an unmanaged area at Pow Hill. Care was taken to ensure the least disturbance to this soil, so simulating the conditions at Pow Hill. The pots were subsequently treated with combinations of fertilizer, lime and seed, as explained below, and left in the Botany gardens in Durham.

Fertilizer treatment was achieved using John Innes Potting Fertilizer, which was readily available from the Botany gardens. This was composed as follows:

13% Nitrogen

18% Phosphorus

48% Sulphate of potash

In common with farming practice, applications were made at 4 cwt./acre (451,144g/ha) and 2 cwt./acre (225,572 g/ha). The fertilizer was sprinkled over the soil surface at the time of seeding. Though acidic in nature (pH = 4.5) the fertilizer and soil acidity were compatible. The use of lime alleviated its effect in most cases in the experimental treatments.

Liming was made possible using Magnesium limestone obtained from Coxhoe quarry. This was the same source as that used at Pow Hill in 1970, but was devoid of the larger granules, now visible on the soil surface of the managed areas. By trial, it was found that 5 g. per pot gave pH$>$6.5 when mixed with the first 1 cm. of soil.

The seed mixture used consisted of the following species:

8 parts Chewing's fescue (<u>Festuca rubra var. commutata</u>)

5 parts Creeping fescue S.59 (<u>Festuca rubra</u>)

3 parts <u>Agrostis tenuis</u>

It was obtained from the parts department of Durham County Council and was the same as that used at Pow Hill. All pots received 1 g. of this mixture.

The following pots were prepared:

N - Soil + seed

NF_1 - soil + seed + NPK at 2 cwt/acre (1.7 g/pot)

NF_2 - soil + seed + NPK at 4 cwt/acre (3.4 g/pot)

N Ca - soil + seed + lime

NF_1Ca - soil + seed + lime + NPK at 2 cwt/acre

NF_2Ca - soil + seed + lime + NPK at 4 cwt/ acre

Six replicates were made. The pots were arranged in a latin square and were left for nine weeks, being attended with distilled water only when wilting occurred.

At the end of nine weeks, the growth produced was analysed by recording length of leaves, root penetration and dry weight of the aerial growth.

Results

1. Germination studies

The results of germination studies are shown below. In each case, maximum germination over a seven day period was recorded. Each sample contained 25 seeds.

Species	% Germination
Festuca rubra	44
Festuca rubra var. commutata	96
Agrostis tenuis	4

Chewing's fescue was the first to germinate, and was the more robust of the species tested.

2. Growth Studies

Continuous observation was made during the growing period and the results of these are summarised below.

May 10th Experimental growth work begun.

May 13th N and NCa pots were first to produce coleoptiles.

May 15th NCa pots showed best growth.

May 29th NF_1Ca appeared better growing than others.

June 9th NF_2Ca appeared better growing than others.

July 11th Experiment stopped.

Plate 2 shows the comparative growth of the treatments on May 22nd.

The results of the experiment are recorded in figures 27 and 28.

Discussion

Germination studies revealed poor viability of A. tenuis seeds and good germination of Chewing's fescue. Such results explain the results of the growth studies. The quicker germination of Chewing's fescue may assist in its establishment in competition with other species. It was unfortunate that growth studies had already progressed when this difference in viability was observed. Results from Pow Hill suggest that the mixture used in 1970 contained A. tenuis seeds with good viability. The development of A. tenuis under different mineral conditions was not able to be tested.

Growth studies showed that lime plus high fertilizer treatment gave greatest yield. Lower fertilizer treatment with lime was capable of producing a greater overall yield than high fertilizer treatment alone.

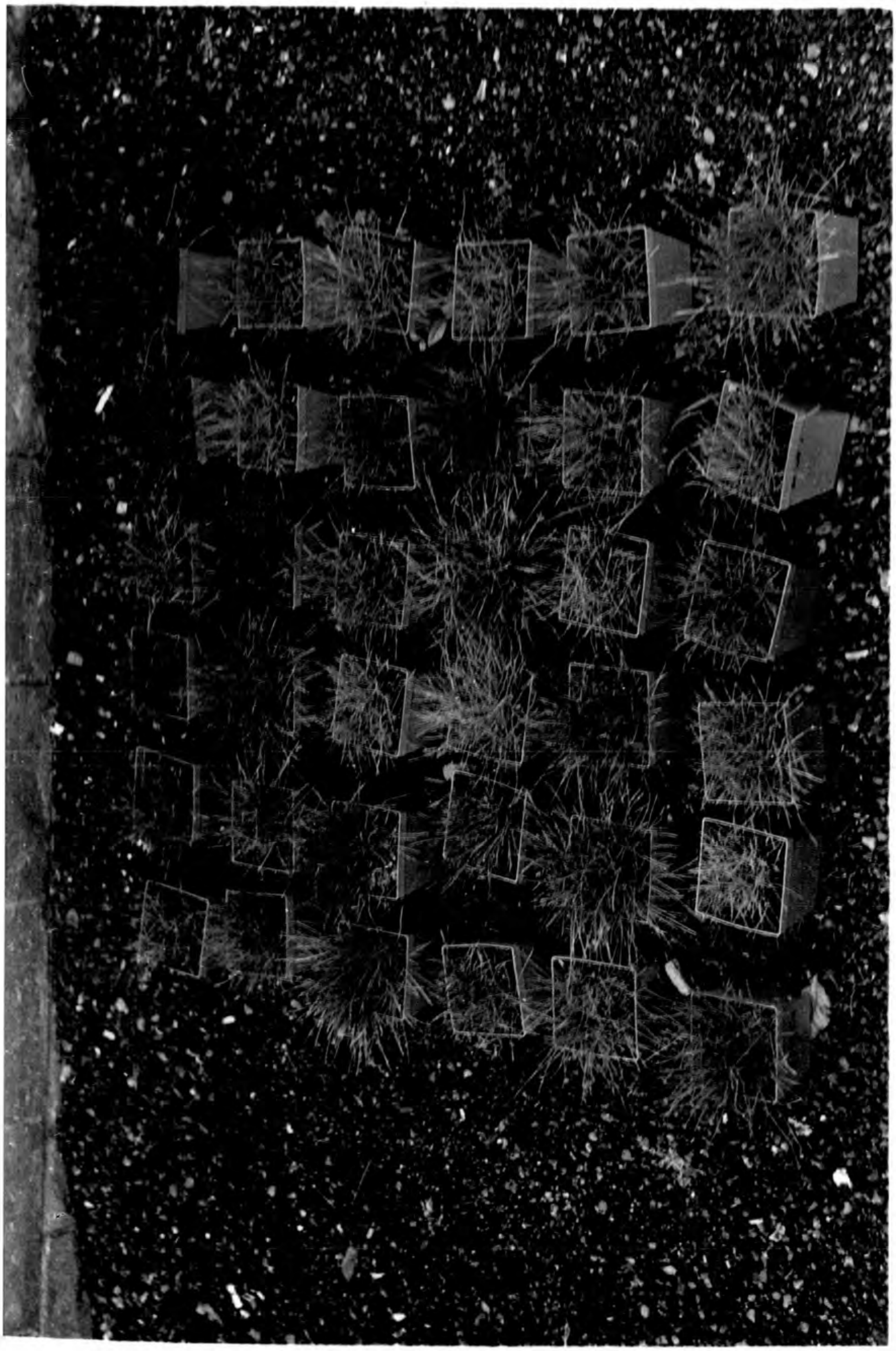


Plate 2. Pot experimental work on seed mixture.

Figure 27. Dry weights and heights of results of Pot experiments.

Dry Weight

Treatment	Replicates. Weights in grams. 1	2	3	4	5	6.	Mean	S.D.
N	0.66	0.46	0.65	0.92	0.85	0.67	0.70	0.15
NCa	0.98	1.05	0.95	1.12	0.55	0.82	0.91	0.19
NF_1	1.57	1.06	1.84	1.48	1.19.	1.46	1.43	0.25
NF_2	1.82	1.23	1.62	1.76	1.61	1.28	1.55	0.19.
NF_1Ca	1.92	2.13	1.86	2.13	1.84	1.08	1.83	0.35
NF_2Ca	2.61	2.45	2.25	1.92	1.69.	2.70	2.27	0.36

MAXIMUM HEIGHT

Treatment	Replicates. Heights in cms. 1	2	3.	Mean
N.	3.8	4.7	4.6	4.4
NCa	5.5	6.0	8.2	6.6
NF_1	8.7	10.3	6.8	8.6
NF_2	9.6	9.5	8.0	9.0
NF_1Ca	7.4	8.3	9.2	8.3
$NF_2Ca.$	10.5	9.8	12.3	10.9.

Figure 28. Root Penetration and Soil pH results of pot experiments.

Root Penetration

Replicates. Depth in cms

Treatment	1	2	3	Mean.
N	0·7	0·6	0·5	0·6
NCa	0·9	1·1	1·4	1·1
NF_1	1·0	0·5	0·3	0·6
NF_2	0·9	0·8	1·1	0·9
NF_1Ca	0·7	0·8	1·2	0·9
NF_2Ca	1·2	1·0	0·8	1·0

Soil pH.

Treatment	1	2	3	4	5	6	Mean	S.D.
N	4·8	4·8	5·3	5·2	5·3	5·0	5·1	0·22
NCa	5·7	5·9	5·9	4·9	5·7	5·3	5·7	0·38
NF_1	4·4	4·8	4·9	4·4	4·6	4·6	4·6	0·19
NF_2	5·7	5·2	5·0	4·6	5·0	5·5	5·2	0·36
NF_1Ca	5·2	5·2	5·2	5·3	5·0	5·2	5·2	0·09
NF_2Ca	5·4	5·1	5·7	4·8	4·9	5·0	5·2	0·31

The presence of lime alone was capable of improving yield, probably by changing the ion exchange capacity of the soil, thereby facilitating mineral uptake.

The performances observed took place in a pH range comparable to those existing on managed paths at Pow Hill. Any future plan for fertilizer addition to these paths should be aware of the relationship with pH conditions.

All plants, in all treatments, experienced great difficulty in root penetration. It was believed that this inability to ensure good soil attatchment would leave such grasses vulnerable to the effects of erosion by public pressure.

Problems and future work

It was regretted that mineral uptake analysis was not possible. In particular, it would have been valuable to compare the uptake with performance in *A. tenuis*, *D. flexuosa* and *F. rubra var. commutata* at different mineral treatments. From such work an understanding of each grass and its mineral requirements at Pow Hill could have been reached.

Conclusions

In a seed mixture with poor viability of *A. tenuis*, *Festuca rubra var. commutata* and *Festuca rubra* showed greatest yield with high fertilizer treatment at pH$>$5.0.

DEVELOPMENTAL WORK

Introduction

In addition to the detailed examination of public pressure on the Country Park, a number of qualitative approaches were made, to gain some insight to the wider aspects of the problem. Though the scientific approach can be criticised, it is believed that the results obtained have some relevance to the work in this dissertation.

(a) Artificial Trampling Experiment

Method

An area of proven untrampled grassland on path 8 (see figure 19) was used to study the detrimental effect of public pressure on the species present. Before trampling the vegetation consisted of *Festuca rubra var. commutata* (Chewing's fescue), *Deschampsia flexuosa*, *Agrostis tenuis* with some *Festuca rubra* (creeping fescue), but with occasional other species occurance.

Three paths, adjacent and parallel to each other, were marked out. The first of these was subjected to 50 tramples a week, the central area was untouched, and the third was given 100 tramples a week. The paths were approximately 0.5 m. wide and 10 m. in length.

Trampling was carried out personally, once a week, wearing walking boots. The nature of trampling was a mixture of walking and running up and down the artificial paths. Care was taken to keep the proportions of these two activities equal on both paths, approximately in a 2:1 ratio. This mixture was related to the pressure experienced on paths of the central hill.

A photographic record was made of these paths at intervals, together with weekly notes on the growth of the grasses. The trampling was stopped in late July when soil and vegetation analyses were carried out.

Results

(a) The photographic record of path formation with continuing public pressure is shown in plates 3-6. The 100 tramples per week path is shown on the left in all photographs.

(b) Weekly observations of both paths showed that whilst the vegetation of the central area continued to increase in height, the grasses on both paths decreased in height initially, and were stunted in form thereafter. Grasses on the heaviest trampled path showed yellowing, indicating dead tissue within two weeks, and this trend continued in the following weeks. Grasses on the lighter trampled path were able to continue growth between the trampling periods and consequently, though unable to show an increase in height, always showed fresh growth in this period.

(c) Vegetational analysis of the paths is shown in figure 29. In each case the position of the trampled regions is shown in relation to the species recorded. The transects differed from others analysed in that points were put at 5 cm. intervals along the transect line.

(d) Collections of plants were made from the central parts of both paths, to examine their morphology and to provide further evidence to substantiate the results of the transects. The result of this work is shown below.

Path	Plants examined	Chewing's fescue	Deschampsia flexuosa	Agrostis tenuis	Notes
100 tramples per week	30	9	6	15	All plants within 1-3 cms height
50 tramples per week	50	17	14	14	All plants within 2-4 cms height
Control (no trampling)	50	19	15	15	Plants up to 2-5 cms height

(e) Soil analysis

The pH of the soil at the start of trampling was 6.1. In the control area, this was maintained at the end of the trampling period. On both the

Trampling Experiment

Plates 3 - 6

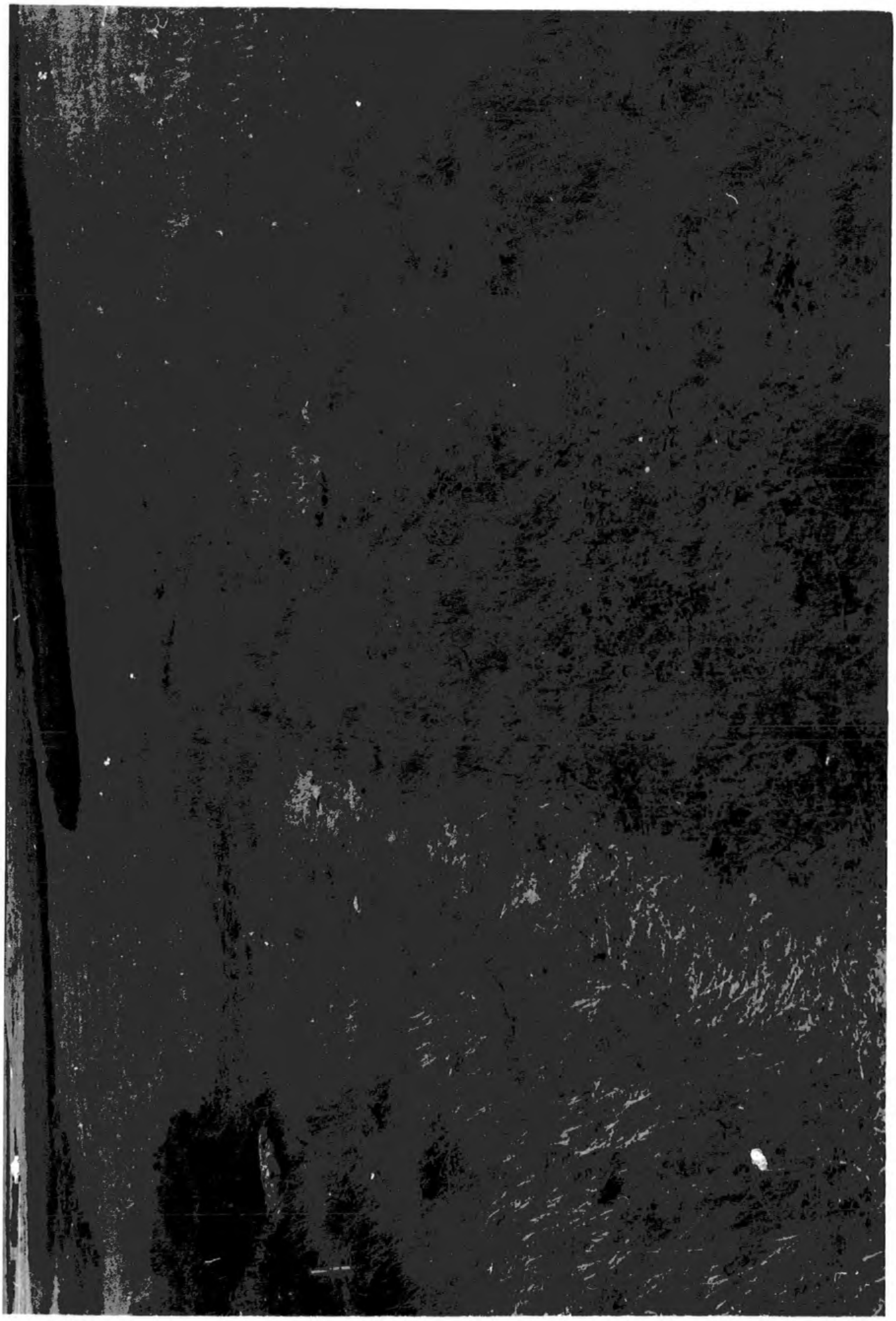


Plate 3. Trampling experiment at 400/200 walkovers.

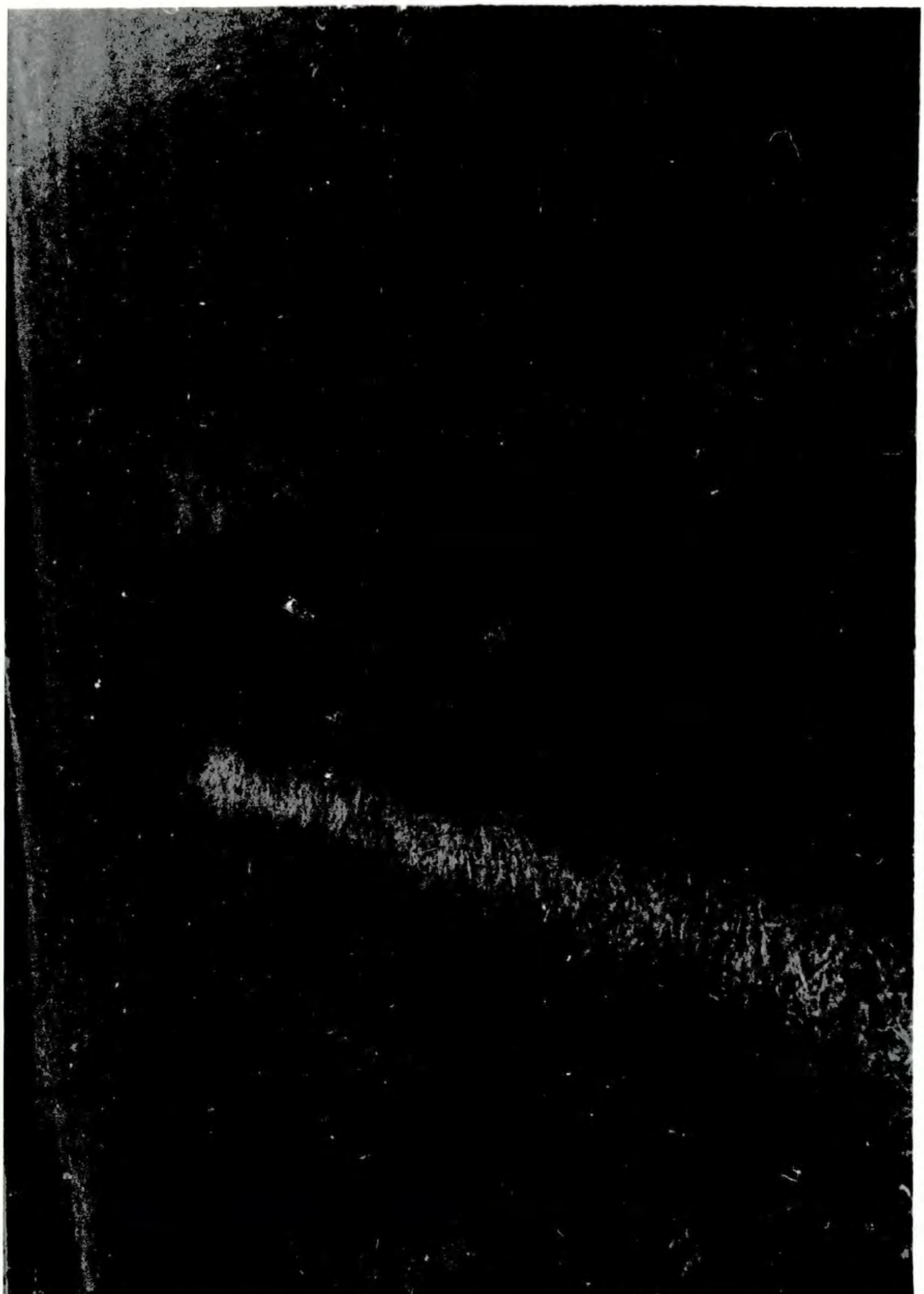


Plate 4. Trampling Experiment at 800/400 walkovers.

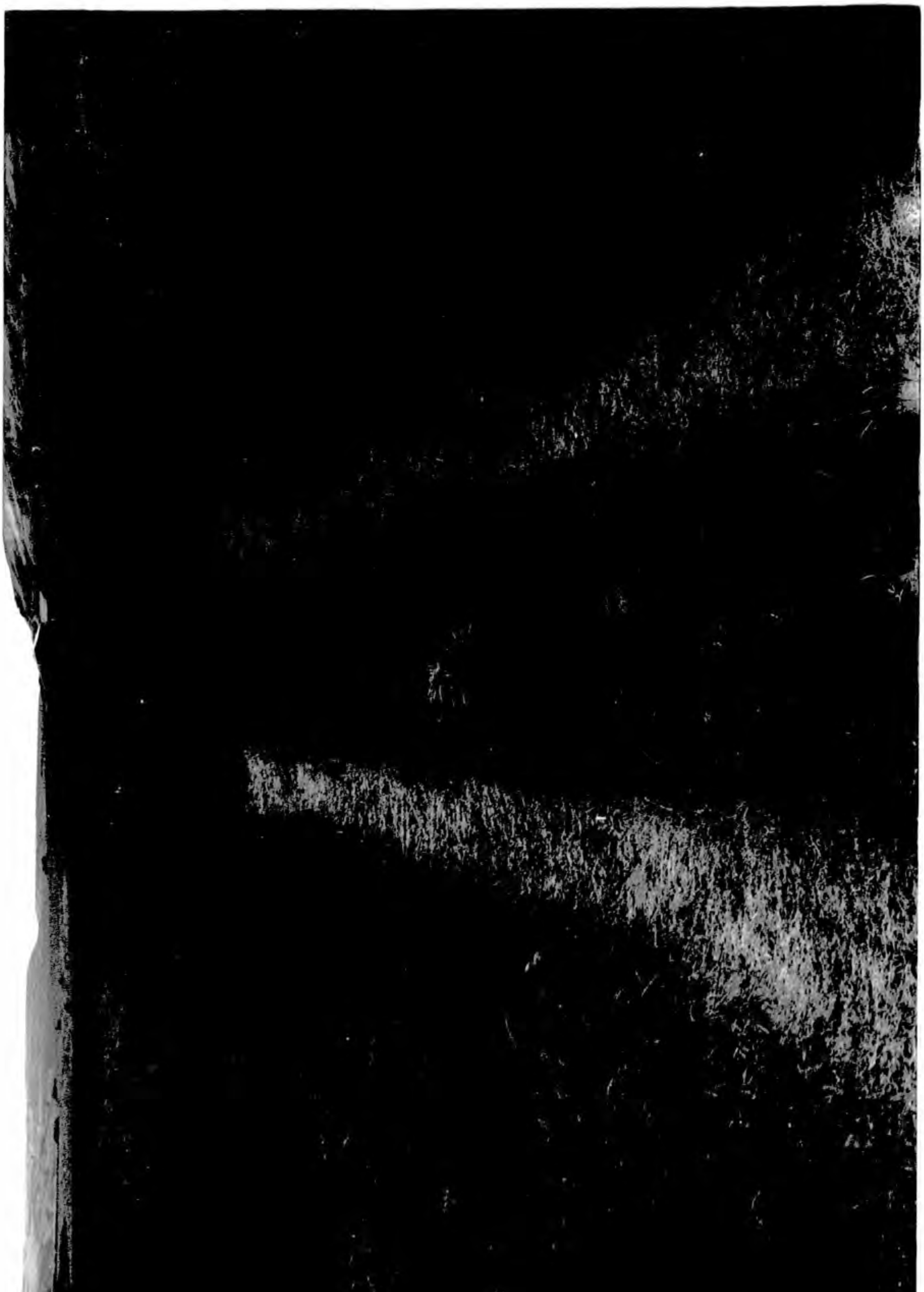
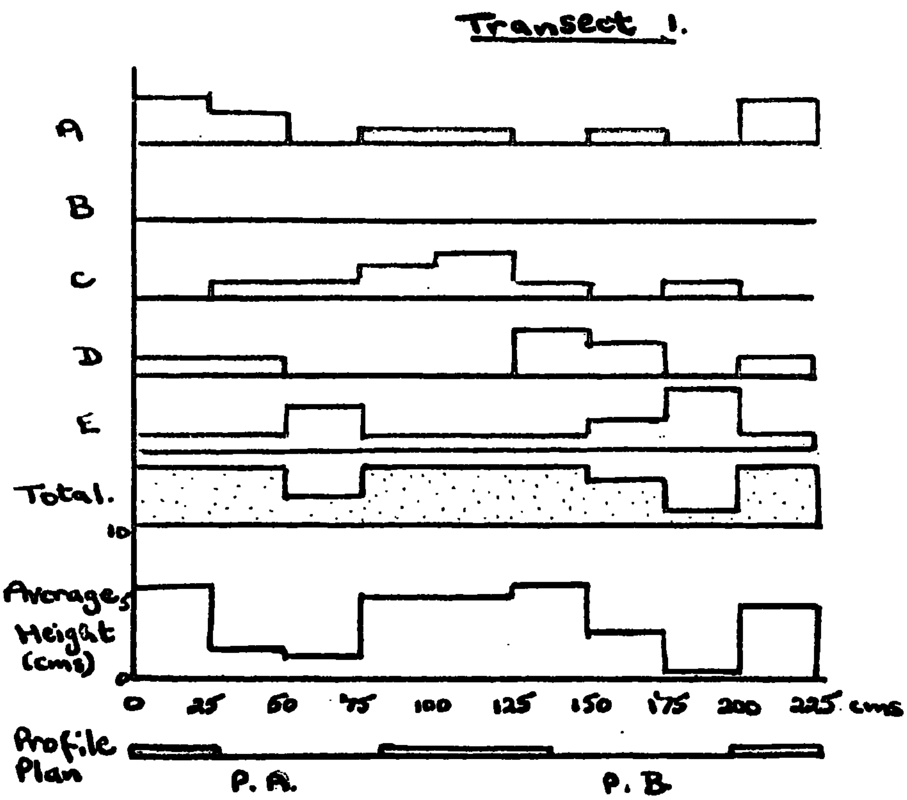
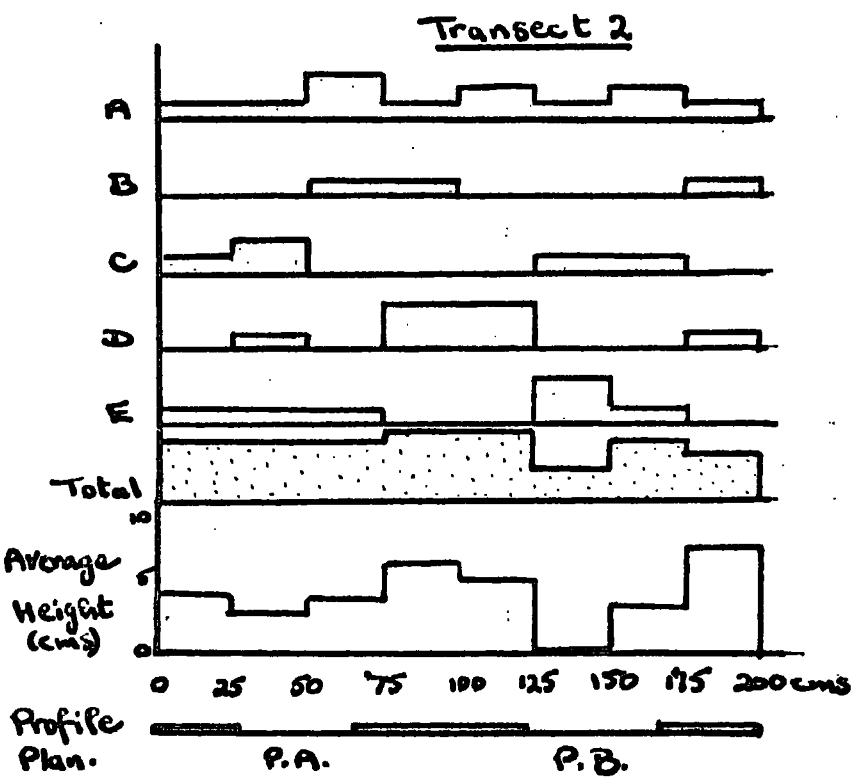


Plate 5. Trampling Experiment at 1000/500 walkovers.

Plate 6. Trampling Experiment at 1200/600 walkovers.

Figure 29. Results of Transects across artificial trampling area.





Key: P. A. – Path produced from 50 walkovers per week.
P. B. – Path produced from 100 walkovers per week.

trampled areas, pH values between 6.5 and 8.5 were recorded, the value varying from location. Highest values were recorded in areas where small lumps of Magnesium limestone had persisted on the soil surface, which had been crushed in the course of trampling, thereby raising the pH values.

Soil profiles were made at the start and end of the trampling. The results are recorded below:

	Control	50 trample path	100 trample path
Start	0.5 cm light humus covering 4.5 cm peaty soil		
Finish	0.5 cm light humus 4.5 cm peaty soil	trace of light humus 5 cm peaty soil	5 cm peaty soil

Dry weights and ash-free dry weights were not attempted.

Discussion

From the work carried out, it was noticeable that vegetation and soil deterioration followed a similar pattern to that observed on managed paths on the central hill.

The belief that trampling effects were cumulative, (Bayfield, B.E.S. Symposium, 1971) was often reflected in this work. Plant recovery on the less trampled path continued between treatments throughout the experimental period, and apart from loss of height, gave the appearance of a moor area. At this pressure, plant death and removal was not seen to occur. Soil profiles confirmed this view, emphasising the point that plant removal is associated with soil erosion.

Under heaviest trampling pressure, both soil erosion and plant removal was observed. It was clear that plant recovery between tramples was not always occurring, leaving dead tissue which was mechanically removed at the next trampling period. Fragments of dead Calluna stems were believed to have an erosion effect on the soil. They were noticed mainly on the heaviest trampled path, where soil erosion was greatest.

It was thought that under severe trampling, a point was reached at which tussocks of grass were uprooted leaving the ground open for further erosion, with the reduced opportunity for other species to colonise. Insufficient time was available in the experimental work to test this hypothesis.

The survival of A. tenuis, on the heavily trampled path showed that its morphology gave some survival advantage. It further confirmed the pattern of vegetation cover that was observed on paths 5 and 7 on the central hill. The plants found were small, probably having a competitive disadvantage with Chewing's fescue in open sward, but liable to increase their cover now this had been largely removed.

The relatively low frequency of C. vulgaris on these paths did not allow for any study of its survival in relation to the grasses.

2. Transplant work

Method

The aim of this work was to gain some understanding of the effects of trampling pressure on untrampled and recovery rates of heavily trampled vegetation. In May, 1972, 4 squares of soil and vegetation, measuring 20 cm^2 and 9 cm depth, were transplanted between untrampled and trampled locations.

The untrampled area was part of path 8 (see figure 1) and paths 3, 4, 5 and 6 were selected as trampled areas. At the time of transplant the grasses had hardly commenced seasonal growth, the difference in height and mat formation being the result of the previous season's growth.

The transplanted vegetation was left until early August, 1972, when a visual inspection was made of plant performance.

Results

It appeared that in all cases, the squares adjusted to their removal to a new area, since widespread dead tissue was not observed.

The effect of subjecting untrampled vegetation to public pressure was to reduce its height and flowering potential completely. After two months public pressure, the vegetation persisted in all four sites, and apart from density showed a superficial similarity to the surrounding vegetation, both in height and form. No detail analysis was made at this stage, in view of parallel work being carried out in the trampling experiment.

The rate of recovery of trampled vegetation transplanted to an untrampled location was most obvious, even in the short time allowed. One of these transplants, taken from path 4 was photographed at the start and end of this work and is shown in plates 7 and 8. A brief summary of observations between the recovered vegetation and the vegetation on the path of origin is given below. All measurements refer to height of the vegetation found.

Location	Vegetation in transplant	Vegetation on Path of Origin
Path 3	Mainly bare. 1 plant of A. tenuis (11 cms.) Some moss development	Mainly bare. Plants with height not exceeding 1 cm. Moss absent.
Path 6	Species found: Pteridium aquilinium (5 cm) A. tenuis (4 cm) Deschampsia flexuosa (5 cm)	All species not exceeding 2 cms.
Path 5	Species found: D. flexuosa (2 cms) A. tenuis (3 cms) and some moss	All species not exceeding 1 cm.
Path 4	Good sward development seen. A. tenuis (7 cm) D. flexuosa(5 cm) P. pratensis (6 cm) C. vulgaris(2cm) Chewing's fescue (10 cm) + some moss	All species not exceeding 2 cms. C. vulgaris not common. No moss seen.

Discussion

Without further scientific approach to this work, no tentative conclusions can be made. It was interesting to observe, however, that both height reduction of squares transferred to trampled situations and recovery rates of the squares transferred to untrampled locations was very rapid.

The significance of these results was seen to be relevant in relation to a proposed management of the area. If the public were prevented from using the heaviest trampled paths for a few months of the growing season, the grasses already present on the paths would recover quite well. Combined with observations in section 5.3, the improvement of trampled regions could be considerable.

3. Artificial seeding at Pow Hill

Methods

Some reseeding of damaged paths, whilst allowing normal visitor pressure was attempted in June, 1972. Strips of seeding was carried out on paths 5, 6, 7 and 15 (see figure 1). The strips were 0.5 m wide and covered the complete width of the path.

In view of the viability of the seed mixture tested (see section 4), it was decided to use the seed mixture sent by Sutton's Seeds Ltd., for this work. This mixture, recommended for upland acid soils, consisted of the following species:

3 parts *Festuca longifolia* (hard fescue)

3 parts *Festuca rubra* S.59 (creeping red fescue)

2 parts *Agrostis tenuis*

2 parts *Festuca rubra var. commutata* (Chewing's fescue)

It was sown by hand at high density and covered with light damp soil to encourage germination.

Results

The results of this work were recorded in descriptive form only. Within two weeks from seeding, young grass was observed at all locations. Growth continued during July, but was subjected to increased public pressure, resulting in some erosion and uprooting on paths 5 and 6.

By August good sward development was seen at the sides of all paths. No analysis was made at this point, as it was considered that this experiment was still under progress. It was hoped to examine these areas over the following year.

Plate 7. Vegetation transplant from path 4. May, 1972.

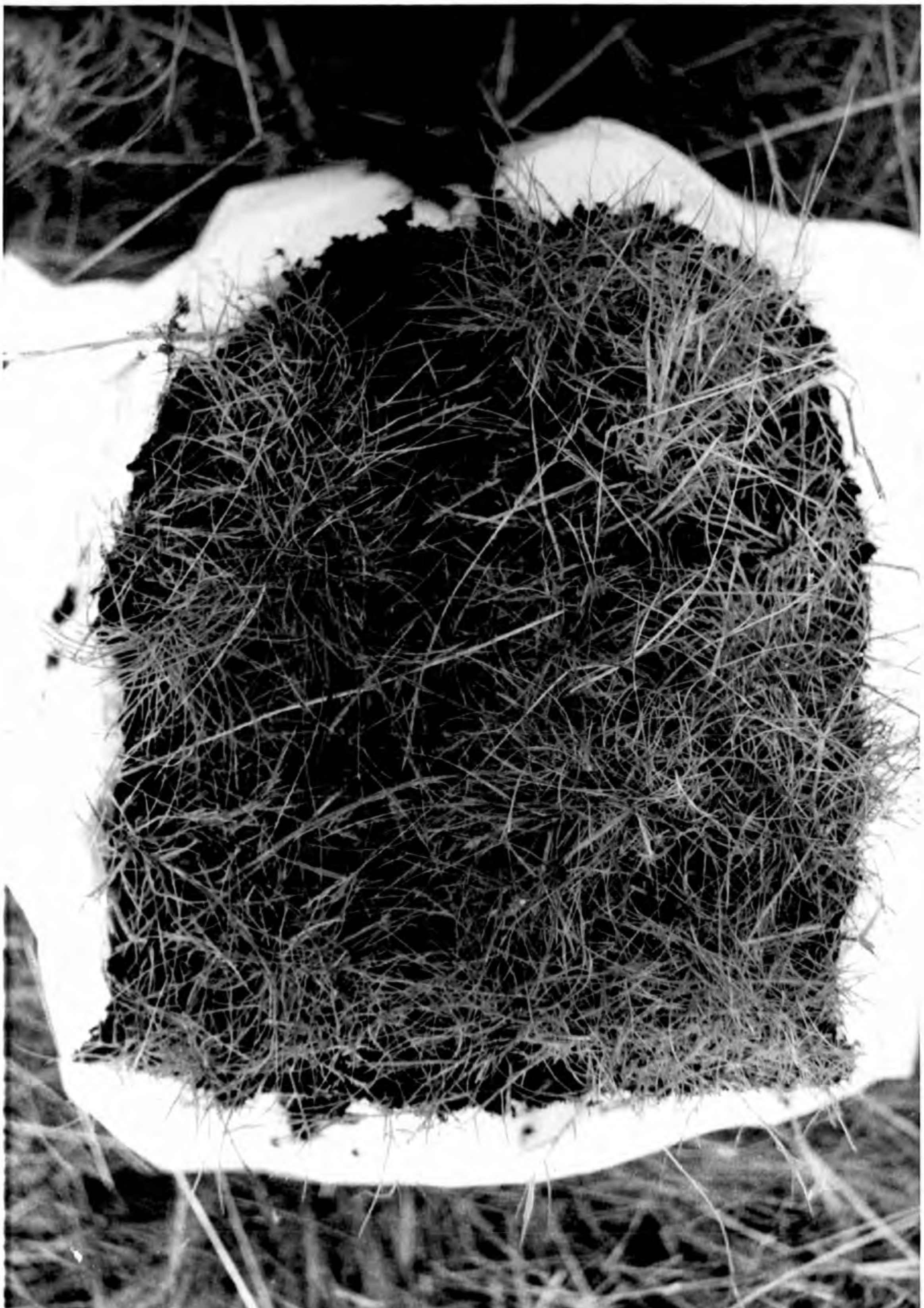


Plate 8. Vegetation transplant from path 4. August, 1972.

Discussion

Since work at Pow Hill did not commence until May, it was not possible to reseed at a more favourable time than described. In view of the comparatively higher public pressure, during June, July and August, it would be advisable to either seed in late autumn or in early spring in future.

Work carried out in section 3c has shown that seedling survival of seed sown in 1970 has not been good where public pressure has been high. Combined with some means of reducing pressure over the summer months, greater success should be possible.

It was not possible at this stage in the work to determine the success of the seed mixture used. It has already been shown that A. tenuis performed well under public pressure, and that sowing this species may be preferred to the mixture described here.

The value of reseeding was realised, and it was suggested that such work be undertaken before next summer, by which time, the results from these trials will have been established.

4. Visitor Survey

Method

The aim of this survey was to discover why the public were not using the southern hill of the country park, whilst maintaining a heavy trampling pressure on the central hill.

No detailed questionnaire was prepared. Durham County Planning Department had already carried out a visitor survey on 11th and 18th June to determine certain aspects of public movement, but had not collected information concerning precise movement of people at the Country Park. Such information was regarded as necessary in view of the proposed car parking extension.

Visitors were asked two questions when they had finished walking over the paths, and were returning to their cars. These were:

Question 1. Why did you walk on this central hill rather than the (southern) hill over there?

Question 2. If I told you there was a good view from that hill, would you go there?

Answers were obtained on Sunday afternoons, during the peak periods. A total of 22 people were sampled.

Results

Though most answers to the questions were individual, they followed a general pattern. This is shown below:

Question 1

Most direct way to view the reservoir	15
Most obvious paths to follow	4
Other answers	3

Question 2

Did not know there were paths over there	8
How would I get up to the top?	5
Do not believe it would give a good view	4
Other answers	5

Discussion

It was clear that heavy usage of paths on the central hill resulted both from their proximity to the car parking area and to the good views they allowed of the reservoir. Some of the people questioned had not visited the country park before, and consequently followed others along the paths. With the extension of the car parking area around the valley, it was considered likely that the majority of extra visitors would follow this trend under the present arrangements.

The southern hill, and its associated paths, was an unknown quantity to most visitors. Many showed interest in walking on the area once informed of its path network and the good views that could be enjoyed at the top.

The main problem in this respect, was one of access. Cars were unable to park as close as they could to the central hill, and there was no major managed or unmanaged path to the top. One small path (path 18) became apparent only after marshy ground had been traversed, and consequently was rarely used. The obscure position of the only other path (path 17) to this hill meant that the public were generally not aware of its existence.

The warden has reported that only when the central hill was crowded, as at peak periods, did the public spread onto the southern hill.

CONCLUSIONS

1. An ecological study of Pow Hill Country Park was undertaken to determine the effects of public pressure on both unmanaged and managed vegetation. It was hoped that the results would help define a management plan for the area.

2. Trampling effects were most severe on unmanaged paths. Their narrow width concentrated trampling pressure, resulting in both stunted plant growth and plant removal. Only Deschampsia flexuosa was found to tolerate moderate pressure, but it was unable to survive on path centres.

3. On managed paths the following vegetation gradient was established:

   A. tenuis > D. flexuosa > F. rubra var. commutata > C. vulgaris

   The success of A. tenuis on heavily trampled paths was attributed to its compressed morphology. The inability of C. vulgaris to survive moderate trampling pressure provided a means of preventing reversion of paths to heather moor.

4. Many 'weed' species took advantage of open habitats on paths; of these, Poa pratensis, Cerastium holostiodes and Trifolium repens were most frequent, and appeared to tolerate moderate trampling pressure.

5. Mineral experiments showed greatest yield of Chewing's fescue with 4 cwt/acre fertilizer at pH 5.2. Without liming, yields were much reduced at all three levels of treatment.

6. Experimental trampling of untrampled managed grassland confirmed the persistence of A. tenuis under heavy pressure. Chewing's fescue

and *D. flexuosa* showed some recovery between treatments when subjected to moderate pressure.

7. Children played a major role in vegetation destruction and soil erosion. New paths were likely as a result of their running through untrampled heathland.

8. Transplant work indicated a rapid recovery of trampled grassland when relieved of pressure during the growing season.

9. Experimental seeding of managed paths resulted in good germination on all paths treated, and good growth on paths subjected to moderate pressure.

10. A survey showed a marked public preference for using heavily trampled paths on account of their proximity to the car parking area, and by providing good views over the reservoir.

11. The ecological carrying capacity of most paths on the central hill had probably been reached. Further deterioration of paths and heathland was probably averted by poor weather during the summer of 1972, resulting in a reduced public pressure.

RECOMMENDATIONS FOR FUTURE WORK

In the light of conclusions reached in this dissertation, the following recommendations are offered for the management of Pow Hill Country Park.

1. Provision of further car parking space around the hill should be subject to several conditions:

   (a) A large section of bog be retained so that visitors, especially children, might appreciate the nature of such a community. This would mean a reduction of parking area, but would enforce the aims of a country park.

   (b) The extra visitor load should be spread over a greater proportion of the country park. In particular there is an immediate need for access to the southern hill from the valley side. Two managed paths are suggested, both about 5 m. wide with gentle inclines to encourage visitors to walk on them. One would extend from the position of unmanaged path 18 to the present car park limit. This should be available for next spring and be well-signposted. The other should accompany the extensions, its route depending on such extensions, but aimed at leading to the back of the southern hill.

   This increased pressure on the southern hill will help reduce <u>Calluna</u> growth on paths and encourage a grass carpet through increased tillering.

   (c) Periodically all visitors to the park should be prevented from using the central hill and be directed to the southern hill. This could be done initially in conjunction with re-seeding of the central hill (see below) and could be controlled by signs at the entrance to the park, together with a small group of people at the car park areas to direct visitors up the newly formed paths. A trial run of this plan is suggested for 1973 to acquaint visitors with this under-used area.

2. The central hill should be re-seeded on the most heavily trampled areas either in Autumn, 1972 or Spring, 1973. The seed most suitable for these areas would appear to be *Agrostis tenuis* (brown bent). Under heavy pressure, Chewing's fescue would not be recommended.

   Following seeding, the whole central hill should be prohibited to visitors for two months. This could be achieved by the placing of rope barriers and an explanatory notice at the start of each access path. This measure would allow a latent period during which both seeding and regrowth of trampled vegetation could take place.

3. Periodic monitoring of path wear, species performance and further breakdown of heathland is suggested. In the light of such results, decisions could be taken for closing the central hill to visitors in future years. In particular, the relative success of *A. tenuis* and *D. flexuosa* could be recorded.

4. The effect of children on untrampled heather areas requires some attention. It is possible that after initial paths are produced, the remaining *Calluna* will continue to grow well since no burning plan is likely, such growth will compensate for the inability of *Calluna* seedlings to establish on the paths.

5. Further mineral studies of both soil and plants on paths would be worthwhile, especially in relation to path erosion and compaction, The recommendations produced are limited by the lack of such data.

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Appendix

POW HILL GRID 1

Quadrats / Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
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Quadrats / Species	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	Total
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Visitors at Pow Hill 1971

(Warden's Records)

Dates (mainly Sundays)	Total Maximum	Peak Maximum	Weather at Park
4.4	22	6	Rain
11.4	200	110	Sunny
13.4) Easter	357	150	Sunny
14.4)	222	120	Sunny
18.4	164	48	Dull
28.4	335	123	Sunny
2.5	487	195	Sunny
9.5	634	203	Sunny
16.5	471	184	Sunny
23.5	30	8	Rain and Fog
30.5	378	135	Cool and windy
6.6	55	18	Cool and windy
13.6	128	46	Cool and windy
20.6	100	46	Rain and Fog
27.6	447	164	Sunny
4.7	617	250	Sunny
11.7	1,082	430	Sunny
18.7	580	220	Sunny
25.7	970	540	Sunny
1.8	86	42	Rain
8.8	715	250	Sunny
29.8	970	540	Sunny
5.9	1,739	555	Sunny
12.9	1,169	525	Sunny
19.9	474	231	Cool wind

Total visitors observed on these days was 10,661.

Visitors at Pow Hill 1972

(Warden's Records)

Dates (mainly Sundays)	Total Maximum	Peak Maximum	Weather at Park
9.4	540	262	Dull
15.4	166	85	Cool
16.4	489	172	Cool and dull
19.4	85	45	Fine
22.4	67	23	Cool and dull
23.4	292	124	Cool and dull
9.5	200	63	Rain
14.5	618	269	Dull
17.5	82	46	Rain
20.5	359	162	Sunny
21.5	993	435	Sunny
25.5	98	32	Sunny
27.5	92	31	Rain
28.5) Whit	714	268	Sunny but cool
29.5)	?	?	Cool
3.6	279	78	Sunny
4.6	744	318	?
10.6	46	14	Rain and cool
11.6	415	175	Rain
14.6	126	52	Dull
17.6	200	71	Rain
18.6	392	152	Showers
25.6	334	130	Dull and cool
29.6	88	33	Dull
1.7	304	103	Sunny
6.7	164	60	Sunny
8.7	364	114	Sunny
9.7	558	228	Dull
15.7	521	172	Sunny
16.7	1,545	660	Sunny
19.7	212	78	Sunny
23.7	391	176	Rain and fog

Dates (mainly Sundays)	Total Maximum	Peak Maximum	Weather at Park
26.7	423	135	Sunny
29.7	345	140	Rain
30.7	842	340	Dull
2.8	330	133	Sunny
5.8	152	61	Dull
6.8	555	256	Dull and rainy.

Total visitors observed
on these days was 14,125.